RESPONSE OF *LINUM USITATISSIMUM* L. TO THE APPLICATION OF GA_3, N, P, Ca AND Mg

ABSTRACT

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IN

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DEPARTMENT OF BOTANY
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Abstract of the thesis submitted to the Aligarh Muslim University, Aligarh, India in partial fulfilment of the requirements for the award of the degree of Doctor of Philosophy in Botany, 2008.

Five factorial randomized pot experiments were performed during the 'rabi' (winter) seasons of 2003-2007 on *Linum usitatissimum* L. (linseed). The data of the experiments are summarized below.

Experiment 1 was conducted during the winter season of 2003-2004 to find out the best GA_3 treatment for five newly released cultivars of linseed, namely Laxmi 27, Parvati, Rashmi, Shekhar and Shubhra. There were three GA_3 treatments, viz. 0, 10^{-8} and 10^{-6}M, with each treatment consisting of pre-sowing seed treatment followed by foliar spray on 40 days old plants raised from the treated seeds. The plants were grown with the uniform recommended dose of 90 kg N, 30 kg P and 30 kg K/ha, i.e. 40.2 mg N, 13.4 mg P and 13.4 mg K/kg soil. The performance of the crop was assessed in terms of growth characteristics, namely height per plant, leaf area per plant, leaf area index, fresh weight per plant and dry weight per plant; physiological and biochemical parameters, viz. P_N, CA activity, leaf chlorophyll and N, P and K content studied at 60 and 75 DAS; and yield and quality characteristics (capsules per plant, seeds per capsule, 1000-seed weight, seed yield per plant, biological yield per plant, harvest index, oil content, oil yield per plant, iodine value, fibre yield per plant and lodging) at harvest.

The important results are as follows:

Pre-sowing seed and foliar treatment with GA_3 at 10^{-6}M proved best for most of the parameters studied. This treatment enhanced, for example, dry weight per plant by 40.5% and P_N by 12.2% at 75 DAS and seed yield per plant by 24.7%, oil yield per plant by 27.1% and fibre yield per plant by 55.9% at harvest over 0 M GA_3 (control). However, as presumed, GA_3 treatments increased lodging, with 10^{-6}M GA_3 increasing it by 43.7% compared with the control.

The data revealed that cultivars differed critically with regard to parameters studied. Cultivar Shubhra, followed by Parvati and Shekhar for some parameters,

including seed yield per plant and oil yield per plant, performed best. Shubhra showed improved dry weight per plant by 65.2% and P_N by 13.8% at 75 DAS and seed yield per plant by 15.8%, oil yield per plant by 17.9% and fibre yield per plant by 35.5% at harvest over Laxmi 27 which gave the minimum values.

Of the interactions, 10^{-6}M GA_3 x Shubhra gave the maximum value for most of the parameters. This interaction enhanced dry weight per plant by 131.6% and P_N by 27.2% at 75 DAS and seed yield per plant by 44.8%, oil yield per plant by 49.7% and fibre yield per plant by 105.8% at harvest over 0 M GA_3 x Laxmi 27 which gave the lowest values. The (undesirable) increase in lodging in 10^{-6}M GA_3 x Shubhra compared with 0 M GA_3 x Laxmi 27 was 67.4%.

Experiment 2 was performed on the three better performing cultivars, viz. Parvati, Shekhar and Shubhra selected on the basis of the data of Experiment 1, during the winter season of 2004-2005 to test if combination (s) of basal N and P other than the one applied in Experiment 1, could improve the performance of these cultivars grown with a uniform basal dose of 30 kg K/ha and treated with the best pre-sowing seed and foliar spray dose of GA_3 (10^{-6}M) of Experiment 1. Four graded levels of N and P, i.e. 0 kg N + 0 kg P/ha (N_0P_0), $N_{30}P_{10}$, $N_{60}P_{20}$ and $N_{90}P_{30}$ were applied. The important results are summarized below.

Treatment $N_{60}P_{20}$ proved superior for most parameters studied. This treatment increased dry weight per plant by 51.5% and P_N by 10.9% at 75 DAS and seed yield per plant by 83.3%, oil yield per plant by 97.3% and fibre yield per plant by 78.7% at harvest over N_0P_0 (control).

Among cultivars, Shubhra again proved best. It enhanced dry weight per plant by 17.1% and P_N by 10.7% at 75 DAS and seed yield per plant by 10.5%, oil yield per plant by 14.8% and fibre yield per plant by 10.5% at harvest over Parvati which gave the lowest values.

The interaction $N_{60}P_{20}$ x Shubhra gave the maximum value for most parameters. It increased dry weight per plant by 73.1% and P_N by 23.6% at 75 DAS and seed yield per plant by 104.8%, oil yield per plant by 130.3% and fibre yield per plant by 86.8% at harvest over N_0P_0 x Parvati which gave the minimum values. Here again, $N_{60}P_{20}$ x Shubhra increased lodging by 3.4% compared with N_0P_0 x Parvati.

Experiment 3 was conducted on the same three better performing cultivars of linseed (Parvati, Shekhar and Shubhra) during the winter season of 2005-2006. This experiment was laid out to test if foliar spray of Ca could enhance their performance.

Four doses of Ca, namely 0 kg Ca/ha (Ca_0), Ca_1, Ca_2 and Ca_3 were applied at 40 DAS. The cultivars were grown with the pre-sowing seed and spray treatment of GA_3 (10^{-6}M) and the dose of N and P (with K_{30}), i.e. $N_{60}P_{20}K_{30}$, that had proved best in Experiment 1 and Experiment 2 respectively. The important findings are given below.

(i) Foliar spray treatment of Ca at 2 kg/ha (Ca_2) proved best for most of the parameters. This treatment increased, for example, dry weight per plant by 34.3% and leaf Ca content by 61.1% at 75 DAS and seed yield per plant by 69.9%, oil yield per plant by 74.9% and fibre yield per plant by 85.7% at harvest over Ca_0 (control). Moreover, it reduced lodging of the crop by 4.9% compared with the control.

(ii) Cultivar Shubhra again maintained its superiority for most of the parameters studied. It enhanced dry weight per plant by 33.1% at 75 DAS and seed yield per plant by 14.5%, oil yield per plant by 15.5% and fibre yield per plant by 4.3% at harvest over Parvati which gave the minimum values.

(iii) Interaction Ca_2 x Shubhra proved best for most of the parameters. This interaction enhanced dry weight per plant by 78.2% and leaf Ca content by 106.3% at 75 DAS and seed yield per plant by 91.9%, oil yield per plant by 90.1% and fibre yield per plant by 90.2% at harvest over Ca_0 x Parvati which gave the minimum values. Interestingly, Ca_2 x Shubhra decreased lodging of the plants by 19.0% compared with Ca_1 x Parvati which was at par with Ca_0 x Parvati in its effect and gave the maximum value for lodging.

Experiment 4 was carried out simultaneously with Experiment 3 on the same three better performing cultivars of linseed to test the efficacy of Mg spray. In this Experiment, four foliar spray doses of Mg, viz. 0 kg Mg/ha (Mg_0), $Mg_{0\ 5}$, $Mg_{1\ 0}$ and $Mg_{1\ 5}$ were tried at 40 DAS. As in Experiment 3 on Ca spray, the cultivars were grown with the best pre-sowing seed as well as spray dose of GA_3 (10^{-6}M) and the basal nutrient dose, i.e. $N_{60}P_{20}K_{30}$, that gave the maximum values for most parameters in Experiment 1 and 2 respectively. The important results are summarized below.

(i) Foliar spray treatment $Mg_{0\ 5}$ proved best for most of the parameters. Spray treatment $Mg_{0\ 5}$ enhanced , for example, dry matter by 25.8%, P_N by 17.4%, leaf chlorophyll content by 17.3% and leaf Mg content by 11.7% at 75 DAS and seed yield per plant by 24.8%, oil yield per plant by 27.4% and fibre yield per plant by 21.6% at harvest over Mg_0 (control). Moreover, $Mg_{0.5}$ decreased lodging of the plant by 1.9% compared with the control.

(ii) Among cultivars, Shubhra again performed best for most of the parameters studied. It increased dry weight per plant by 56.0%, P_N by 13.3%, leaf chlorophyll content by 8.1% and leaf Mg content by 15.7% at 75 DAS and seed yield per plant by 19.1%, oil yield per plant by 27.6% and fibre yield per plant by 11.2% at harvest over Parvati which gave the lowest values.

(iii) Regarding the interactions, $Mg_{0.5}$ x Shubhra proved best. This interaction improved dry weight per plant by 86.4%, P_N by 29.5% and leaf chlorophyll content by 27.2%, leaf Mg content by 26.8% at 75 DAS and seed yield per plant by 48.3%, oil yield per plant by 63.0% and fibre yield per plant by 35.6% at harvest over Mg_0 x Parvati which gave the lowest values. Moreover, $Mg_{0.5}$ x Shubhra decreased lodging by 14.4% compared with Mg_0 x Parvati which gave the maximum value for lodging.

Experiment 5 was conducted on the same three better performing cultivars of linseed during the winter season of 2006-2007. This experiment was based on the data and methodology of Experiments 3 and 4. It was planned to test if combined Ca and Mg spray could increase their efficacy further. The crop was subjected to four combinations of foliar spray of Ca and Mg, viz. 0 kg Ca + 0 kg Mg (Ca_0Mg_0), Ca_2Mg_0, $Ca_0Mg_{0.5}$ and $Ca_2Mg_{0.5}$ at 40 DAS. The results are summarized below.

(i) The combination of Ca_2 and $Mg_{0.5}$ ($Ca_2Mg_{0.5}$) proved best for most of the parameters. This treatment improved, for example, dry weight per plant by 20.6%, P_N by 19.1% and leaf chlorophyll content by 25.7%, leaf Ca content by 21.3%, leaf Mg content by 8.6% at 75 DAS and seed yield per plant by 39.6%, oil yield per plant by 46.9% and fibre yield per plant by 36.9% at harvest over Ca_0Mg_0 (control). Moreover, $Ca_2Mg_{0.5}$ decreased lodging of plants by, 4.0% and 12.5% compared with Ca_2Mg_0 and $Ca_0Mg_{0.5}$ respectively.

(ii) Cultivar Shubhra maintained its superiority in this experiment also. It improved dry weight per plant by 19.3%, P_N by 5.8% and leaf chlorophyll content by 3.3 % at 75 DAS and seed yield per plant by 14.1%, oil yield per plant by 19.8 % and fibre yield per plant by 6.2% at harvest over Parvati which gave the lowest values.

(iii) The interaction $Ca_2Mg_{0.5}$ x Shubhra gave the maximum values for most of the parameters. This interaction enhanced dry weight per plant by 40.1%, P_N by 25.1% and leaf chlorophyll content by 28.8%, leaf Ca content by 41.9% and leaf Mg content by 32.3% at 75 DAS and seed yield per plant by 61.3%, oil yield per plant by 75.7% and fibre yield by 44.1% at harvest compared with Ca_0Mg_0 x Parvati which gave the lowest values. Moreover, $Ca_2Mg_{0.5}$ x Shubhra decreased lodging of plants by 35.9% compared with $Mg_{0.5}$ x Parvati which was at par with Ca_0Mg_0 x Parvati and gave the maximum value for lodging. Interestingly, $Ca_2Mg_{0.5}$ x Shubhra also decreased lodging by 31.3% and 35.9% compared with Ca_2Mg_0 x Parvati and $Ca_0Mg_{0.5}$ x Parvati respectively, thus establishing the higher efficacy of the combined spray of Ca and Mg in lowering lodging in Shubhra.

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DEPARTMENT OF BOTANY
ALIGARH MUSLIM UNIVERSITY
ALIGARH (INDIA)

2008

Dedicated

To

My Parents

Firoz Mohammad
MSc., MPhil, PhD, DSc
FBS, FISSP, Gold Medalist (AAAS)

Professor of Botany

Department of Botany
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Dated: February 8, 2008

THESIS

Certificate

This is to certify that the thesis entitled "**Response of *Linum usitatissimum* L. to the Application of GA_3, N, P, Ca and Mg**" submitted in partial fulfilment of the requirements for the award of the degree of Doctor of Philosophy in Botany, is a faithful record of the bonafide research work carried out at The Aligarh Muslim University, Aligarh by **Mr. Mohd. Nasir Khan** under my guidance and supervision and that no part of it has been submitted for any other degree or diploma.

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(Mohd. Nasir Khan)

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Introduction

Chapter 1

INTRODUCTION

The world food supplies are usually debated in terms of cereals, wheat, rice and maize being the dominant commodities, but there exists a second group of crops, the oilseeds, which make a major contribution to human diet both in the peasant's hut and in the international hotel. On the oilseed map of the world, India's vegetable oil economy is world's fourth largest, being one of the important oilseed growers, producers, importers and, paradoxically, exporters (Hegde, 2006). The diverse agro-ecological conditions of the country are favourable for growing all the annual oilseeds which include groundnut, rapeseed-mustard, soybean, sunflower, sesame, niger, safflower, castor and linseed. These have played a key role in the agricultural economy of India from time immemorial.

Oilseeds are not only a source of oil but also of proteins, sugars, minerals and even vitamins. Oils (and fats) are recognized as essential nutrients in both human and animal diets. Nutritionally, they are concentrated sources of energy; provide essential fatty acids, which are the building blocks for the hormones needed to regulate bodily systems and are carrier for the oil-soluble vitamins A, D, E and K. On the kitchen front, they act as tenderizing agents, facilitate aeration, carry flavours and provide a heating medium for food preparation. Besides edible oils, non-edible oils also play a vital role in everyday life owing to their various uses in industries, like fuel, grease, hair oil, lubricant, paint, soap and varnish. The protein-rich cake, obtained after crushing, is a valuable feed for livestock.

As far as linseed is concerned, it is used in various ways. Its seeds are used for the extraction of its oil. About 80% of linseed oil goes for industrial use and the remaining 20% for edible purpose (Verma *et al.*, 2005). Linseed oil is, therefore, primarily an industrial oil used in the manufacture of paints, varnishes, linoleum, oil cloth, printing and lithographic ink and soft soap. Relatively small amounts are used in linings and packings, leather finishing compounds and also in protective coatings and emulsifying agents (Anonymous, 2003). The fibre extracted from its stem is used in the manufacture of canvas, coating, durries, shirting and strong twines. The good quality fibre is used for the manufacture of linen. The woody matter, left after the removal of fibre, is used for the manufacture of paper (Samba Murty and Subrahmanyam, 1989).

Linseed is officially included in the Indian pharmacopoeia. The whole seed is prescribed as a laxative. The mucilaginous infusion, linseed tea as it is called, is used internally as a demulcent for colds, coughs and bronchial affections, inflammations of the urinary tract, gonorrhoea and diarrhoea. Crushed seed is applied in the form of a poultice for the relief of local inflammations and ulcers, boils and carbuncles (Anonymous, 2003).

According to an estimate for the year 2005, India accounts for about 448.7 thousand hectares with a seed production of 169.7 thousand tonnes and occupies the fourth rank among the linseed producing countries. The average yield of linseed in India (378.2 kg/ha) is, however, far behind the averages of Australia (1000 kg/ha) and Canada (1346.9 kg/ha), the world average being 1008.35 kg/ha. Similarly, the productivity of other oilseeds in India is also comparatively less than that of other countries (FAO, 2007).

In India, the low productivity of oilseeds is due to several factors. A few of these are described here: (i) More than 75% of Indian farmers own small or marginal holdings of less than two hectares, (ii) Only 15% of the area under oilseeds is under irrigation compared with 75% under wheat and 44% under rice, (iii) Most farmers are ignorant of the techniques of cultivation of high yielding varieties, post-harvest technology and proper processing facilities, (iv) About one third of flowers produced do not develop into fruits, (v) Pests and diseases reduce the yields further as oilseeds are more prone to these, (vi) Prevalent low temperature adversely affects flower bud development and thereby lowers seed yield, (vii) Lack of knowledge of precise dose of fertilizers recommended by the Agriculture Department for a particular cultivar and region, and (viii) Low or no use of fertilizers due to scarcity of funds. Further, it has been established that species of a genus (and even varieties of a species) differ, in their ability to fully utilize inputs, including nutrients, under the same environmental conditions (Millikan, 1961; Evans and Sorger, 1966; Siddiqui, 1999).

Therefore, to meet the challenges of low oilseed production, there is need to adopt a multipronged strategy which involves enhancing oilseed production through area expansion and productivity improvement through adoption of improved technology. To achieve this goal, the Indian Council of Agricultural Research has established more than sixty research centres in different regions of the country to deal with various oilseed crops, including one for linseed improvement at Kanpur (Uttar Pradesh). Also, many research projects have been launched by non-government organizations to boost the production of oilseeds. However, it must be admitted that these effects howsoever laudable have not yet succeeded in offsetting the undesired shortfall in the indigenous oil market. To meet the situation, the country has been importing huge quantity of oilseeds every year. For example, in the year 2005, even with record oilseeds production of 281.6 thousand tonnes, India imported 30.81 thousand tonnes of oilseeds including 0.99 thousand tonnes linseed (FAO, 2007).

Commercial cultivation of linseed for both seed and fibre is clearly not cost effective and attempts have been made to produce a dual-purpose linseed crop with good yield of both seed and fibre. However, little progress has been made in breeding dual-purpose varieties synchronized for both seed yield and fibre quality. Under these circumstances, the best strategy for dual-purpose linseed would be to increase the height of the plant and to improve seed weight, a task which may prove simpler than achieving the synchronization of seed and fibre maturity.

Like other high yielding crops, the requirement of oilseeds for nutrients is high. Some of the intensive cropping systems involving oilseeds may remove much of the applied nutrients under high productivity conditions. Also, increasing use of high analysis fertilizers results in a growing deficiency of secondary nutrients and micronutrients. Further, much of the fertilizer is rendered unavailable to the plants if applied as a single dose at sowing due to many factors. For example, up to 50% of the applied nitrogen (N) may be lost through leaching, decomposition, volatilization etc. (Anonymous, 1971; Dejoux, 2003) and up to 70% of the phosphorus (P), by fixation (Russell, 1950; Gikaara *et al.*, 2004). Thus, for achieving the desired productivity, the limiting nutrients need to be supplied judiciously using innovative methods of application.

As mentioned earlier, a majority of farmers (75%) has marginal holdings of less than two hectares. Therefore, with such a limitation on increasing the acreage for cultivation, it is highly desirable to innovate ways which can augment the yields. One such approach could be to make plants utilize fully the available resources leading to maximum harvesting of solar energy and subsequently increasing the number of active sinks. To achieve this, plant growth regulators could be used as they are known to affect many facets of plant life, including growth, flowering, fruiting and ion transport (Wareing and Phillips, 1981; Khan *et al.*, 2002; Khan and Samiullah, 2003).

Gibberellins are known to control a wide range of physiological functions in plants. For example, application of gibberellic acid (GA_3) improves growth, cell elongation and cell differentiation thus augmenting plant height. Therefore, the present author proposed to apply GA_3 to linseed to increase stem height for better harvesting of solar energy for maximum utilization of its potential for seed, oil and fibre production. However, this favourable effect on growth and development could be offset, at times, by substantial loss in yield due to lodging. To counter this, it is proposed to strengthen the fast growing stem by some means. In this regard, application of calcium (Ca) and magnesium (Mg) might prove helpful in providing mechanical support to the plants by strengthening the middle lamellae of stem cells in the form of calcium and magnesium pectate.

It was, therefore, decided to undertake five pot experiments with the following objectives in mind:

(1) To determine the best concentration of GA_3 for pre-sowing seed and spray treatment required for the optimum performance of five linseed cultivars grown with the recommended dose of N, P and K and to select the most effective concentration of GA_3 and one (or more) cultivar of linseed suited best to the conditions obtaining locally.

(2) To test whether application of a combination of N, P and K other than the recommended one could augment the growth, yield and quality of the selected linseed cultivar (s) grown with the best pre-sowing seed and spray treatment of GA_3.

(3) Lastly, to test if foliar spray of dilute solutions of Ca and/or Mg could improve the performance of the selected cultivars further by reducing the lodging due to GA_3 treatment.

The details of the five experiments planned with these objectives in mind are given in Chapter 3 (pp. 29-32).

Review of Literature

CONTENTS

Chapter 2

REVIEW OF LITERATURE

Farm scientists have been working on various crops, including linseed, for improving their performance through a combination of high yielding varieties, improved crop management practices, plant protection measures, proper nutrition and hormonal balance. In the following pages, an attempt has been made to review the available literature on general aspects of linseed, gibberellins, plant mineral nutrients and on the response of the crop to GA_3, N, P, K, Ca and Mg application:

2.1 Linseed

Linseed and flax are alternative types of the same species *Linum usitatissimum* L. The former is cultivated mainly for oil and the latter for fibre. Linseed is known by different names in different languages of India. For example, in Bengali, it is called masina; in Gujarati, alsi; in Hindi, alsi and tisi; in Kannada, agasi; in Marathi, javas; in Sanskrit, atasi; in Tamil, alivirani and in Telagu, avisi. It belongs to family Linaceae which comprises 22 genera. Genus *Linum* is the most well known and includes more than 200 species divided in five subsections. Subsection *Linum* contains the cultivated species *Linum usitatissimum* L. and the ornamentals *Linum grandiflorum* Desf. and *Linum perenne* L. Species of the genus are mostly herbs and shrubs and are distributed along the temperate and sub-tropical parts of the globe. Four species, namely *Linum mysorense* Heyne, *Linum perenne* L., *Linum strictum* L. and *Linum usitatissimum* L., are recorded from India (Anonymous, 2003; Reddi and Reddy, 2003).

2.1.1 Botanical description

Linseed is an annual herb with erect, slender, 60-120 cm tall stems. The stem has little branching except at the apex. Leaves are small, alternate, simple, linear to linear-lanceolate, three veined, entire, exstipulate and grayish green. Inflorescence is scorpioid cyme. Flowers are bisexual, pentamerous, hypogynous, pedicellate, complete and blue or white. Sepals are ovate, acuminate, 3-nerved, quincuncial and persistent. Petals are free, claw-shaped, arranged alternately to sepals, blue or white and contorted. Androecium consists of 10 stamens in two whorls (the outer one reduced to staminodes and the inner one united at the base to form a ring). Gynoecium is pentacarpellary, ovary syncarpous superior, 5 locules appearing 10, because of the formation of a false septum, one ovule in each chamber, axile placentation, free style and linear clavate stigma. Fruit is a 5-celled capsule with persistent sepals, 8-10 seeds and septicidal dehiscence. The seeds are oval, somewhat flattened, 4-6 mm long, pale to dark brown and shiny.

2.1.2 Classification

Based on the system of classification given by Bentham and Hooker (1862-1883), linseed could be classified as follows:

Kingdom	-	Plant kingdom
Division	-	Phanerogamia
Sub-Division	-	Angiospermae
Class	-	Dicotyledons
Sub-class	-	Polypetalae
Series	-	Disciflorae
Order	-	Geraniales
Family	-	Linaceae
Genus	-	*Linum*

2.1.3 Origin and distribution

Linum usitatissimum L. is unknown in a wild state and its origin is uncertain. It is considered by some to be closely related to or derived from *Linum bienne* Mill. (syn. *Linum angustifolium* Huds.) which occurs wild in the Mediterranean region. Some consider it to be indigenous to localities between the Persian Gulf and the Caspian Sea and the Black Sea, while others ascribe its origin to India. Two main geographical groups corresponding to the oldest areas of cultivation and centres of diversity may be recognized. The first group comprises oil types growing areas of south-west Asia, including Turkistan, Afghanistan and India and the second group, fibre flaxes cultivating region, viz. Mediterranean coastal lands, Asia Minor, Egypt, Algeria, Tunisia, Spain, Italy and Greece. However, there is also a third group which consists of both oil and fibre forms cultivating area i.e. Asia Minor and South Russia. Recently, a study with molecular markers suggested that these species originated from one common ancestor, with *Linum angustifolium* Huds. being the most ancient (Anonymous, 2003; Muravenko *et al.*, 2003).

Presently, linseed is cultivated on a large scale in Argentina, China, India, Ireland, Japan, Morocco, Pakistan, Poland, Scotland, Uruguay, USA, the member countries of the former USSR and a few European countries (Samba Murty and Subrahmanyam, 1989; Anonymous, 2003).

At present, India accounts for 20% of the world acreage and 12% of production. Among the major oil seed crops grown in India, linseed accounts for 12% of the total acreage and occupies the fourth place. It is grown all over India, except Delhi, Kerala, Manipur, Tamilnadu and Tripura (Anonymous, 2003).

2.1.4 Climate and soil

Linseed is cultivated throughout the plains of northern India. It is grown predominantly as a rainfed, cold season ('rabi') crop. Areas with the annual rainfall ranging from 45-75 cm are best suited for its cultivation. It grows in almost all types of soil where sufficient moisture is available, except the sandy and badly drained heavy clays, but thrives best in clay loams. It does well in the deep clayey black soils of central and peninsular India and in the alluvium loams of the Indo-Gangetic plains (Anonymous, 2003; Reddi and Reddy, 2003).

2.1.5 Cultivation

Linseed is mainly a winter crop grown all over India. However, its time of sowing varies greatly from region to region. In peninsular India, seeds are generally sown in October to November. In Kashmir, the crop is sown in February and March. Seeds are, as a rule, sown in lines, but in some areas, particularly for growing with a standing crop, seeds are sown broadcast; the latter system is called 'utera' or 'paira'. Under this system, the sowing time is earlier by about a month. Linseed is grown both as a pure as well as a mixed crop. As a mixed crop, it is sown either on margins of the field or in rows alternating with the other crop. In India, linseed is largely grown as a mixed crop with gram, wheat, barley, mustard etc. The crop is harvested in February and March. Plants turn golden yellow when the crop is mature and ready for harvesting. Harvesting is done with a sickle or by uprooting the plants. When the fibre is also desired along with the seed, the harvesting of the crop is done at the stage of capsule maturity even when the crop is slightly green.

The harvested linseed is threshed after it is completely sun-dried. The crop is threshed either by beating it with a stick or by trampling it under the feet of bullocks.

Hand-beating is preferred when fibre, along with seed, is desired. Seed is separated from the chaff by winnowing and is stored in a dry place (Samba Murty and Subrahmanyam, 1989; Anonymous, 2003; Reddi and Reddy, 2003).

2.1.6 Uses

Linseed plants supply both seeds and bast fibres. The bulk of seeds produced in India is utilized for the expression of oil, only a small part is used for sowing, feeding and miscellaneous purposes. Of the oil, 80% goes for industrial purpose and the remaining 20% is used for edible purpose. The oil is highly valued as a drying oil and is taken as a standard for the evaluation of drying properties for other oils. It is used in the manufacture of paints, varnishes, linoleum and oil-cloth, printing and lithographic inks and soft soaps. Relatively small amounts of oil are employed in core oils, linings and packings, oil modified alkyd resins, caulking compounds, putties, leather finishing compounds, lubricants and greases, polishes, plasticizers and pyrotechnic compositions. It is also used as a solvent for industrial stains and for seasoning bobbins (in jute textiles) and cricket bats and other sports goods. Its fatty acids are used in protective coatings and emulsifying agents (Anonymous, 2003).

As stated briefly earlier (p. 2), seeds are demulcent, emollient, expectorant and diuretic. They are astringent after roasting. The whole seed is prescribed as a laxative. The mucilaginous infusion is used internally as a demulcent in colds, coughs and bronchial affections, inflammation of the urinary tract, gonorrhoea and diarrhoea. The mucilage is applied to the eye in irritable conditions of conjunctiva. Crushed linseed is applied in the form of poultice for the relief of local inflammations and ulcers, boils and carbuncle. Linseed poultice is also useful in bronchitis and other deep seated inflammations and has been recommended for gouty and rheumatic swellings (Anonymous, 2003).

Linseed cake obtained after the extraction of oil is highly valued as a protein supplement for live-stock. The mucilage extracted from linseed or linseed cake is used in cosmetic and pharmaceutical industries. Linseed straw yields a fibre which is used as such or after cottonization. Linseed-boll chaff serves as good roughage for cattle and horses. It is a fair source of protein but is deficient in other nutrients. Leaves, cortical tissues of stem and linseed bolls may be used as a low-grade feed for cattle (Anonymous, 2003).

2.2 Gibberellins

Gibberellins cause hyperelongation of intact stems. Gibberellins are also prominently involved in seed germination and mobilization of endosperm reserves during early embryo growth as well as flower and fruit development. Gibberellins are produced by both fungi and higher plants. In the latter, they are synthesized in expanding leaves and shoot apex as also in other parts of shoot, including fruits and seeds and presumably in roots. More than 80 gibberellins are now known and additional members are added every year. A little more than one-third of the gibberellins characterized to date have retained the full compliment of 20 carbon atoms and are known as C_{20}-gibberellins. The others have one carbon atom less and are consequently known as C_{19}-gibberellins. All the gibberellins that are demonstrated to be naturally occurring and that have been characterized are assigned an "A" number (MacMillan and Takahashi, 1968). Gibberellic acid (GA_3), a C_{20} gibberellin (Fig. 1), was one of the first to be isolated and characterized. Because GA_3 is readily extracted from fungal cultures it is also the most common commercially available form, and consequently, is perhaps the most studied of the gibberellins. GA_1 and GA_{20}, both C_{19} GAs, are probably the most active and, consequently the most important gibberellins in higher plants (Hopkins, 1999; Marschner, 2002).

2.3 Plant mineral nutrients

The practice of adding mineral elements (nutrients) to soils as organic manure to improve plant growth is very old and could be traced back from the period of Aristotle (384-322 B.C.) who recognized that the nutritive function separated the living from the dead and the non-living. However, the work of Glauber (1604-1655) and Plattes (1600-1655) is considered as the first scientific evidence of the importance of plant nutrients. They analyzed wood ash, limestone and saltpetre (potassium nitrate) and observed their effect on plant growth and invented a chemical fertilizer called "flattening salt". Woodward (1665-1728) observed that plants can thrive and grow better in muddy water than in clear rain water. The credit for the establishment of the role of mineral matter in plant growth goes to de Saussure (1767-1845). He contributed extensively to the importance of nitrogen (N). Liebig (1803-1873) concluded that the mineral elements N, sulphur (S), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), silicon (Si), sodium (Na) and iron (Fe) are essential for plant growth on the basis of observation and speculation rather than precise

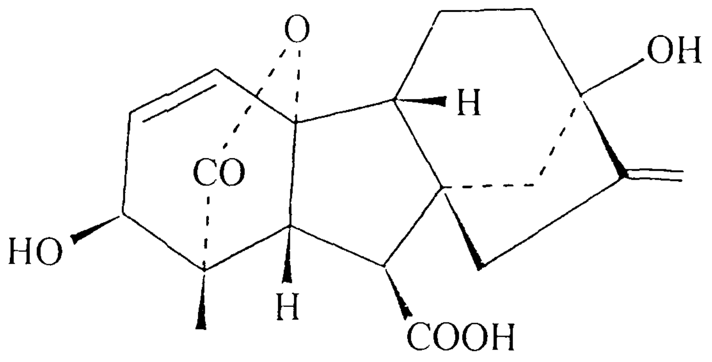


Fig.1: Structure of gibberellic acid

experimentation. However, the true and more advanced developments in plant nutrition began in the 1860s with the attempts made by Pfeffer, Sachs and Knop, whose works resulted in the establishment of the essentiality of ten elements, viz, carbon (C), hydrogen (H), oxygen (O), N, P, K, Ca, S, Mg and Fe (Bould, 1963). In due course of time, the essentiality of using seven other elements, viz. boron (B), chlorine (Cl), copper (Cu), manganese (Mn), molybdenum (Mo), nickel (Ni) and zinc (Zn), has been established on the basis of sophisticated analytical techniques to purify salts and the water for hydroponic cultures (Bould, 1963; Salisburry and Ross, 1992)

2.3.1 Functions of N, P, K, Ca and Mg

2.3.1.1 Nitrogen

Depending on the plant species, development stage and organ, the N content required for optimal growth varies between 2 and 5% of the plant dry weight. Most plants absorb N from the soil solution primarily as inorganic nitrate ion (NO_3^-) and in a few cases, as ammonium ion (NH_4^+). N is a constituent of many important molecules, including amides, amines, amino acids, chlorophylls, enzymes, nucleic acids, peptides, plant growth regulators, proteins and ureides (Mengel and Kirkby, 1996; Hopkins, 1999; Marschner, 2002).

The most overt symptoms of N deficiency are a slow stunted growth and a general chlorosis of the leaves. N is very mobile in plants. Thus, the symptoms of its deficiency generally appear first in the older leaves and do not occur in the younger leaves until the deficiency becomes severe. Conditions of N stress also lead to an accumulation of anthocyanin pigments in many species, contributing a purplish colour to the stems, petioles and the underside of leaves.

Excess N stimulates abundant growth of the shoot system but leads to feebly developed roots. As a result, a high shoot/root ratio occurs. The leaves turn dark green and become thick and leathery, while the plants become susceptible to pests and diseases. Its excess also delays reproductive growth and may affect fruit and grain quality adversely (Black, 1973; Salisbury and Ross, 1992; Scheible *et al.*, 1997; Marschner, 2002).

2.3.1.2 Phosphorus

The optimal growth of a plant requires P in the range of 0.3-0.5% of the plant dry matter. In the soil, P is readily available for the plants as monovalent ($H_2PO_4^-$) and divalent (HPO_4^{2-}) orthophosphate ions. Like N, P is also a constituent of metabolic compounds including nucleic acids, phospholipids, phytin, nicotinamide adenine dinucleotide, nicotinamide adenine dinucleotide phosphate, adenosine triphosphate, pyridoxal phosphate, nucleoproteins, phosphorylated sugars and organic acids, purine and pyrimidine nucleotides and flavin nucleotide (Tamhane *et al.*, 1970; Devlin and Witham, 1986; Raghothama, 1999; Salisbury and Ross, 1992; Hell and Hillebrand, 2001; Marschner, 2002).

Because of the high mobility of P in the plant, the older leaves are usually the first to exhibit deficiency symptoms. The most characteristic manifestations of P deficiency are an intense green colouration of the leaves due to accumulation of anthocyanin and development of necrotic areas on the leaves, petioles or fruits. P deficient plants usually have shortened and slender stems and the yield of the fruits and seeds is markedly reduced. Its deficiency decreases root hair proliferation and elongation, proteoid root formation, association with mycorrhizal fungi and shedding of premature leaves. Its deficiency also delays flowering and fruiting and causes a decrease in photosynthesis and disease resistance (Hewitt, 1963; Devlin and Witham, 1986; Hopkins, 1999; Raghothama, 1999).

Excess of P preferentially stimulates growth of roots over shoots, thus reducing the shoot/root ratio (Hopkins, 1999).

2.3.1.3 Potassium

The K requirement for optimal plant growth is in the range 2-5% of the plant dry weight. It is absorbed by plants as the monovalent cation (K^+). K ion serves to activate a number of enzymes, notably those involved in photosynthesis and respiration (Hopkins, 1999). It plays a role in basic functions, such as cation-anion balance, cell extension, compartmentation and cellular concentration, enzyme activation, osmoregulation, phloem transport, photophosphorylation, photosynthesis and protein synthesis (Maathuis and Sanders, 1996; Marschner, 2002). It is also essential for most other metabolic processes, including glycolysis, oxidative phosphorylation and adenine synthesis (Evans and Sorger, 1966). Movement of K ions is a principal factor in plant movements, such as opening and closure of stomatal guard cells and sleep movements, or daily changes in the orientation of leaves. It has also a motor function in cycling nutrients for growth, e.g. N from roots to shoot and C from source to sink (Krauss, 2001). It is also highly important in enhancing the ability of plants to resist diseases, insect attacks and cold and saline conditions and lodging (Marschner, 2002; Patnaik, 2003).

K deficiency does not immediately result in visible symptoms. At first there is only reduction in growth rate, and only later do chlorosis and necrosis occur. These symptoms generally begin in the older leaves due to its high mobility. Plants suffering from K deficiency show a decrease in turgor and, under water stress, they easily become flaccid. Its deficiency also causes a decrease in photosynthesis, protein synthesis, grain size and yield (Mengel and Kirkby, 1996; Marschner, 2002).

Excess supply of K delays maturity, though not to the same extent as that of N. Plants take up and store K in much larger quantities than what is needed for optimum growth and this excess uptake is known as luxury consumption (Patnaik, 2003).

2.3.1.4 Calcium

Higher plants generally contain appreciable amounts of Ca, usually in between 0.1 and 0.5% of dry weight. Ca is taken up by the plants as divalent cation (Ca^{2+}). In general Ca is involved in a plethora of plant functions. It is an integral part of cell wall and provides cell wall rigidity by cross-linking the pectic chains (calcium pectate) of the middle lamella (Marschner, 2002). Ca is involved in cell elongation and cell division. It influences the pH of cells and also acts as a regulatory ion in the source-sink translocation of carbohydrates through its effect on cell and cell walls. Ca is thought to function as a secondary messenger in the transmission and transduction of several environmental signals, acting as an intracellular metabolic agent. Due to its high affinity to calmodulin and other Ca-binding-proteins, this nutrient might directly control several physiological processes. To fulfil its functions at plasma membrane, therefore, Ca must always be present in the external solution, where it regulates the selectivity of ion uptake and prevents solute leakage from the cytoplasm (Marschner, 2002). It is also a constituent of arginine kinase, adenosine triphosphate, adenyl kinase, potato apyrase and α-amylase. It also stimulates a range of membrane-bound enzymes, particularly ATPase at the plasma membrane of roots of certain plant species (Kuiper and Kuiper, 1979; Rensing and Cornelius, 1980; Hirschi, 2004).

Ca is much less mobile and the Ca deficiency symptoms appear in the youngest tissues first. The meristematic regions are typically affected. Chlorosis occurs along the margins of younger leaves. Later, these areas usually become necrotic. Malformation or distortion of the younger leaves is also characteristic of Ca deficient plants, a hooking of the leaf tip being the most easily detected symptom. The roots of Ca deficient plants are discoloured and may feel "slippery" to the touch because of the deterioration of the middle lamella (Salisbury and Ross, 1992; Hopkins, 1999; Marschner, 2002).

Excessive application of Ca reduces the severity of pathogenic diseases by lowering down the activity of polyglacturonases and pectolytic enzymes secreted by many fungi and bacteria during invasion and infection of plant tissues (Easterwood, 2002).

2.3.1.5 Magnesium

Its requirement for optimal plant growth is in the range of 0.15-0.35% of dry weight. Like Ca, Mg also is taken up as the divalent cation (Mg^{2+}) and is the most abundant divalent cation in the plant cytosol. It is a constituent of cell wall in the form of magnesium pectate. It is the central atom of chlorophyll molecule. It activates many enzymes, including adenosine triphosphatases, carboxylases, glutathione synthetase, phosphatases, protein kinases and ribonucleic acid polymerases. It also acts as a bridging element for the aggregation of ribosomes. Mg helps in the absorption of P (Marschner, 2002; Shaul, 2002).

Mg is also quite mobile and readily withdrawn from the older leaves. Consequently, chlorosis, due to Mg deficiency is most pronounced in the older leaves. Chlorophyll and carotenoid content and the rate of photosynthesis are lower in leaves of Mg-deficient plants and carbohydrates accumulate and there is also a decrease in the starch content of storage tissues such as potato tubers (Marschner, 2002). Plants inadequately supplied with Mg often show a delay of the reproductive phase (Mengel and Kirkby, 1996; Marschner, 2002).

2.4 Sources of N, P, K, Ca and Mg

The removal of plant nutrients by crop uptake, leaching and denitrification is well in excess of nutrient release by weathering and mineralization. A negative nutrient balance thus results unless nutrients are applied in the form of fertilizers or manures to make up the deficit. Generally, the more intensive the cropping system and the higher the yields, the greater must be the amounts of nutrients applied to the soil in order to maintain soil fertility. For most soils, the use of inorganic fertilizers is thus almost essential and a wide range of fertilizers of different grades and nutrient ratios are now marketed (Mengel and Kirkby, 1996). The important sources of N, P, K, Ca and Mg are given below.

N is mainly given in the form of nitrate, ammonium salts, urea or anhydrous ammonia. More specialized fertilizers generally contain N in a more soluble form, such as urea formaldehyde and isobutylidene urea. These forms are slow release N sources. P fertilizers generally contain P in the form of phosphate. Single superphosphate, triple superphosphate, nitric phosphate and ammonium polyphosphate are the major P fertilizers. K is applied to soils mainly in the chloride or sulphate forms, muriate of potash (potassium chloride) and sulphate of potash (potassium sulphate) being the principal K fertilizers. Ca is most commonly applied in the form of pulverized limestone, either calcitic or dolomitic but usually dolomitic. Fertilizer materials such as superphosphates, gypsum, calcium cyanamide and calcium nitrate also carry Ca. It is also supplied through calcium chloride ($CaCl_2$). Mg may be given in a number of forms. The principal ones commonly used are dolomitic limestone (limestone with 20 per cent or more magnesium carbonate), potassium magnesium sulphate, magnesium limestone, magnesium sulphate and magnesite together with its by-products magnesium oxide and hydroxide. Manure salts and kainite also sometimes contain magnesium salts (Collings, 2002).

2.5 Application of growth regulators and nutrients

Generally plants synthesize hormones for their growth and development. However, these may be applied exogenously to ensure better results. There are several methods of application of hormones depending on the plant material and the response for which these are used. The methods include lanolin pasting, dusting, seed soaking and soil and foliar application (Malik, 1999).

Under normal conditions, plants grow in soil and obtain nutrients from it through their root system. However, continuous cultivation results in depletion of nutrients in the soil. To maintain proper fertility of such soils, addition of fertilizers becomes an essential practice. It was, however, found that added fertilizers are rendered partly unavailable to the crops after their application owing to various reasons, including fixation, volatilization and leaching. Moreover, the escalating cost of these fertilizers poses a great problem for farmers in developing countries. With this consideration in mind, farm scientists have developed several fertilizer application techniques to conserve this costly input. These include, soil application, gaseous application, application in irrigation water, banding, broadcasting, strip placement, top dressing, side dressing and foliar application. Of these, the novel technique of foliar application of nutrients seems to be a good alternative to obtain maximum nutrient use efficiency and is preferable when soil application is not feasible (Mengel and Kirkby, 1996; Marschner, 2002).

2.6 Response to the application of GA_3 and N, P, K, Ca and Mg

Environmental conditions, including inputs, influence the growth and development of plants to a great extent. Although some literature is available on the effect of exogenous application of N, P and K on the performance of improved cultivars of linseed the same is not true for GA_3. Also, literature on the response of this crop to Ca and Mg is missing. Under the circumstances, the work done in India for the last two decades or so on the effect of GA_3 application on *Brassica juncea* L. (mustard) is reviewed below, followed by that on the effect of N, P and K on linseed and of Ca and Mg on mustard.

2.6.1 Application of GA_3

Singh and Kumar (1991), performing a field experiment at Pantnagar (Uttarakhand), studied the effect of 0 (water), 1 and 10 ppm GA_3 spray on yield and yield attributes of mustard (cultivar not mentioned). Application of GA_3 spray at 10 ppm proved best for branches per plant, pods per plant and seed yield per plant.

Saran *et al.* (1992), conducting a pot experiment at Patna (Bihar), studied the effect of pre-sowing seed treatment with GA_3 (0, 25, 50, 75 and 100 ppm GA_3) on growth, yield and chlorophyll content of mustard cv. BR 23. They reported that pre-sowing seed treatment with GA_3 increased shoot length, internode length and fresh and dry weights. Seed weight also increased at 50 ppm and above. They also reported that increase in total chlorophyll content at higher concentrations (75 and 100 ppm) of GA_3 was mainly due to increased chlorophyll b content.

Subrahmanyam and Rathore (1992), carrying out a pot experiment at Pantnagar (Uttarakhand), studied the effect of four levels of foliar spray of GA_3 (0, 10, 50 and 100 ppm GA_3) on $^{14}CO_2$ assimilation, partitioning of ^{14}C into major biochemical fractions and translocation of assimilates in different parts of mustard cv. Krishna. They reported that leaves, stem and pod walls were photosynthetically active and were important sources for seed filling. Data revealed that GA_3 increased the export of $^{14}CO_2$ assimilates out of source organs and increased the movement of assimilates into reproductive parts (pods). They suggested that the increased movement of photoassimilates into the developing pods might be due to the growth regulator-stimulated sink activity which resulted in higher demand for assimilates. They also suggested that the growth regulator might increase yield by altering distribution of assimilates in the mustard plants.

Khan (1996) performed a pot experiment on mustard cv. T 59 at Aligarh (Uttar Pradesh). He sprayed plants with 0, 25 and 50 µM GA_3 at the three fully developed leaf stage, viz. 30 days after sowing (DAS) and studied its effect on carbonic anhydrase activity, photosynthetic rate, leaf area index and dry mass at 50, 70 and 90 DAS. At harvest, 1000-seed weight, pod number and seed yield were also recorded. He reported that spray of 50 µM GA_3 proved best for all characteristics studied.

Khan *et al.* (1996) conducted a pot experiment at Aligarh (Uttar Pradesh) to study the effect of three concentrations of N spray (5 mM, 10 mM and 20 mM N) with or without 50µ M GA_3 on carbonic anhydrase and nitrate reductase activities, net photosynthetic rate, leaf area index and dry mass of mustard cv. T 59. They reported that application of 20 mM N inhibited carbonic anhydrase activity, nitrate reductase activity and net photosynthetic rate at 50 DAS. However, when GA_3 was applied in association with the foliar spray of N, the inhibition was reversed and the above parameters, as also leaf area index and dry mass, were enhanced.

Chanda *et al.* (1998), performing an experiment at Rajkot (Gujarat), studied the effect of GA_3 (10 µM GA_3) given in nutrient solution on growth and activities of nitrate reductase and glutamine synthetase in seedlings of mustard cv. Varuna. They found that GA_3 promoted nitrate reductase activity in cotyledons and cytosolic glutamine synthetase activity in root and hypocotyls. However, chloroplastic glutamine synthetase activity was inhibited.

Khan *et al.* (1998) conducted a field experiment on mustard cv. Varuna at Aligarh (Uttar Pradesh) to find out the most suitable growth stage for GA_3 spray. The treatments consisted of foliar spray of deionized water and 10^{-5} M GA_3 given at 40, 60 and 80 DAS. Foliar application of GA_3 enhanced growth, nutrient uptake and yield over water spray treatment. However, leaf area index, seeds per pod, 1000-seed weight and harvest index were not affected. Regarding spray stages, it was added that growth, NPK accumulation and yield were maximum when plants were sprayed at 40 DAS. However, spray treatments at 40 and 60 DAS gave at par values for most of the growth and yield parameters.

Khan *et al.* (2002), conducting a field experiment at Aligarh (Uttar Pradesh), studied the effect of foliar spray of three levels (10^{-6}, 10^{-5} and 10^{-4} M) each of IAA, GA_3 and Kn along with water-sprayed control on growth and yield performance of mustard cv. Varuna grown with a uniform basal dose of 80 kg N + 30 kg P and 30 kg K/ha. Application of GA_3 at 10^{-5} M concentration was found more effective than IAA or Kn treatments in promoting shoot length, leaf number, leaf area, plant dry weight, net assimilation rate and seed and oil yield.

Khan and Samiullah (2003), performing a field experiment at Aligarh (Uttar Pradesh), studied the effect of four levels of GA_3, viz. 0, 10^{-6}, 10^{-5} and 10^{-4} M GA_3 applied through pre-sowing seed treatment for 8 h or foliar spray at pre-flowering stage (40 DAS), on the performance of mustard cv. Varuna. They reported that GA_3 at 10^{-5} M gave the maximum value for leaf area, photosynthetic rate, dry mass, 1000-seed weight and seed, oil and biological yield.

Khan *et al.* (2005), performing a field experiment at Aligarh (Uttar Pradesh), applied 10 μM GA_3 spray on mustard cv. Varuna grown with the three basal levels of S (0, 100 and 200 mg/kg soil). The data revealed that the spray of GA_3 increased specific leaf area, plant dry mass, leaf carbondioxide exchange rate, net assimilation rate and N and S content in plants over the water-sprayed control.

2.6.2 Application of N, P and K

Pawar *et al.* (1990) conducted a field experiment at Rahuri (Maharashtra) on three cultivars of linseed, namely C 429, SPS 23-10 and SPS 49-2, to study the content and uptake of N, P and K and seed and straw yield, under five levels of N, viz. 0, 15, 30, 45 and 60 kg N/ha. They found that content and uptake of N, P and K in seeds as well as seed and straw yield increased with increasing levels of N. It was also reported that seeds showed comparatively higher N content while, straw had higher P and K content. Cultivars SPS 23-10, followed by C 429, showed maximum content as well as uptake of N, P and K and produced maximum seed and biomass.

Yadav *et al.* (1990) performed a field experiment on linseed cv. Jawahar 23 at Sehore (Madhya Pradesh). They supplied four levels of N (0, 30, 60 and 90 kg N/ha) and three levels of P, viz. 0, 15 and 30 kg P_2O_5 (0, 6.5 and 13.1 kg P)/ha. It was reported that increasing levels of N up to 60 kg N/ha increased yield attributing parameters, including seed yield. Further increase in N had no significant effect. However, application of N did not affect oil content. They reported that the application of 6.5 kg P/ha proved optimum for seed yield. On the other hand, capsules per plant and oil content were increased linearly.

Bassi and Badiyala (1992) laid out a field experiment at Malan (Himachal Pradesh) to study the effect of three levels of N, viz. 50, 75 and 100 kg N/ha along with 13 kg P and 25 kg K/ha on plant height, stalk yield, fibre yield and seed yield of linseed (cv. not mentioned). They reported that plant height, fibre yield and seed yield increased with increasing levels of N. However, for stalk yield, application of 75 kg N/ha proved optimum.

Chaubey *et al.* (1992) laid down a field experiment at Kanpur (Uttar Pradesh) to study the effect of graded levels of N, P and S on seed yield and oil and protein content of seed of linseed cv. Garima. The treatments consisted of three levels each of N, viz. 0, 40 and 80 kg N/ha, P, i.e. 0, 25 and 50 kg P_2O_5 (0, 11.9 and 23.8 kg P)/ha and S (0, 30 and 60 kg S/ha). They reported that seed yield and protein content of seed increased with increasing levels of N. Regarding oil content, it was found that N decreased it, while P and S increased it. They concluded that significant responses of linseed to the applied nutrients were up to 80 kg N, 22.8 kg P and 30 kg S/ha.

Chourasia *et al.* (1992a and b), working at Tikamgarh (Madhya Pradesh), studied the effect of all combinations of four levels of N (0, 30, 60 and 90 kg N/ha), four levels of S (0, 15, 30 and 45 kg S/ha) and two levels of B (0 and 1.1 kg B/ha) on the performance of linseed cv. Jawahar 23. They reported that capsules per plant, seeds per capsule ansd N and S uptake increased with increasing levels of N up to 90 kg N/ha.

Patidar and Lal (1992) conducted a field experiment on three cultivars of linseed, namely Chambal, T 397 and RL 102-71 at Udaipur (Rajasthan) to study the effect of four levels of N (0, 20, 40 and 60 kg N/ha) along with a uniform basal dose of 40 kg P_2O_5 (17.5 kg P)/ ha. They found that application of 40 kg N/ha was optimum for capsules per plant, seeds per capsule, test weight and seed yield. However, 60 kg N proved best for straw yield. N had an adverse effect on oil content. The cultivar RL 102-71 followed by Chambal proved best.

Pawar *et al.* (1992) carried out a field experiment on three cultivars of linseed, namely C 429, SPS 23-10 and SPS 49-2 at Rahuri (Maharashtra). They applied five levels of N, viz. 0, 15, 30, 45 and 60 kg N/ha. Application of 45 kg N/ha was reported to be optimum for most of the yield parameters, including seed yield. Regarding cultivars, it emerged that C 429 and SPS 23-10 were equal in producing more seed and straw than SPS 49-2.

Chaubey *et al.* (1993) conducted a field experiment at Kanpur (Uttar Pradesh) to study the effect of four levels each of N (0, 20, 40 and 60 kg N/ha) and S (0, 15, 30 and 45 kg S/ha) alone or in combination on seed yield and N and S uptake by seed and straw yield of linseed cv. Neelam. A uniform dose of 25 kg P_2O_5 (10.9 kg P)/ha was also applied at the time of sowing. They reported that the application of 60 kg N and 45 kg S/ha alone or in combination was more beneficial for seed yield. N application significantly increased N and S uptake by seed and straw.

Kapoor and Singh (1993) performed a field experiment at Palampur (Himachal Pradesh) to study the effect of two levels of N (60 and 90 kg N/ha) and of its method of application on plant weight and stalk weight of linseed (cv. not mentioned). The method of N application included: full at sowing, 1/2 at sowing + 1/2 one month after sowing; 1/2 at sowing + 1/2 at flowering; 1/3 at sowing + 1/3 after one month + 1/3 at flowering; 1/3 at sowing + 2/3 at flowering; 2/3 at sowing +1/3 at flowering and 1/3 at sowing + 1/3 after one month and 1/3 after two months. They concluded that N rates and its methods of application had no significant effect on plant height and stalk weight.

Reddaih *et al.* (1993) performed a field experiment on linseed cv. LH 1 at New Delhi. They applied four levels of N, viz. 0, 40, 80 and 120 kg N/ha along with a uniform dose of 25 kg P and 30 kg K/ha. They reported that increasing levels of N up to 80 kg N/ha increased significantly most of the growth and yield characters, including seed and oil yield. They also noticed that application of N reduced the oil content of seed.

Singh *et al.* (1993) carried out a field experiment on linseed (cv. not mentioned) at Bahraich (Uttar Pradesh). They applied two levels of fertility, viz. a no-fertilizer control and 30 kg N + 20 kg P_2O_5 (8.7 kg P)/ha. Application of 30 kg N + 8.7 kg P/ha improved plant height, number of capsules per plant, seeds per capsule and seed yield over the no-fertilizer control.

Vashishtha (1993) performed a field experiment on linseed (cv. not mentioned) at Bulandshahr (Uttar Pradesh) to study the effect of four levels of N (0, 40, 80 and 120 kg N/ha) and three levels of P, viz. 0, 20 and 40 kg P_2O_5 (0, 8.7 and

17.5 kg P)/ha on (i) yield and yield attributes, (ii) seed quality and (iii) uptake of N and P. He found that increasing levels of N and P increased capsules per plant, seeds per capsule, seed yield per plant and seed yield per hectare. The combination 80 kg N + 17.5 kg P/ha was found to be optimum. He also reported that maximum uptake of N was by the application of the highest doses of N and P. Application of 80 kg N + 17.5 kg P/ha resulted in maximum uptake of N. N at 40 kg N/ha proved superior to other treatments for oil content and iodine value.

Vyas *et al.* (1993) conducted a field experiment on linseed cv. R17 at Sehore (Madhya Pradesh). They applied four levels of N, i.e. 0, 30, 60 and 90 kg N/ha and three levels of P, viz. 0, 15 and 30 kg P_2O_5 (0, 6.5 and 13.1 kg P)/ha. It was found that the application of N up to 60 kg N/ha and P up to 13.1 kg P/ha increased the seed yield linearly.

Dixit *et al.* (1994) performed a field experiment at Powarkheda (Madhya Pradesh) to study the effect of four levels of N, viz. 0, 30, 60 and 90 kg N/ha along with 20 kg P_2O_5 (8.7 kg P) and 20 kg K_2O (16.6 kg K)/ha on growth and yield characteristics of three cultivars of linseed, namely Jawahar 23, Kiran and R 552. They found that the maximum seed yield and net return resulted from the application of 90 kg N/ha. However, plant height, branches per plant, number of capsules per plant, number of seeds per capsule and 1000-seed weight were not affected by N application. Regarding cultivars, R 552 was found to be better performing than the other two.

Dubey and Singh (1994), conducting a field experiment at Lakhaoti (Uttar Pradesh), studied the effect of three levels of N, viz. 0, 50 and 100 kg N/ha along with a basal dose of 40 kg P_2O_5 (17.5 kg P)/ha on yield and yield attributes of linseed cv. Neelam. They reported that capsules per plant, 1000-seed weight, seed yield per plant and seed and straw yield per hectare were enhanced linearly with successive levels of N.

Mohammad (1994), conducting a factorial randomized field experiment at Aligarh (Uttar Pradesh), studied the cumulative effect of leaf-applied and soil-applied N on yield and quality of linseed cv. LHS 1. The treatments consisted of four levels of soil-applied N (25, 50, 75 and 100 kg N/ha) and three levels of leaf-applied N (0, 10 and 20 kg N/ha). A uniform dose of 20 kg P/ha was given at the time of sowing. He reported that basal application of 50 kg N/ha and foliar application of 10 kg N/ha proved best for most of the parameters, including seed and oil yield. It is noteworthy that the combination of the two out-yielded the other combinations, particularly with regard to economy of N fertilizer.

Singh and Mishra (1994) conducted a field experiment at Kanpur (Uttar Pradesh) to study the effect of three levels each of N (0, 40 and 80 kg N/ha) and S (0, 20 and 40 kg S/ha) on their uptake and on dry matter accumulation by two cultivars of linseed, namely Garima and Gaurav, at different stages of growth. A uniform dose of 60 kg P_2O_5 (26.2 kg P) and 60 kg K_2O (49.8 kg K)/ha was applied at the time of sowing. Increasing levels of N and S increased N as well as S uptake and dry matter accumulation. Cultivar Gaurav showed better response at all the stages of growth.

Singh *et al.* (1994) performed a field experiment on three cultivars of linseed, namely Garima, Mukta and Shubhra under dryland conditions at Khandasa (Uttar Pradesh). They studied the effect of four levels of N, viz. 0, 15, 30 and 45 kg N/ha along with a uniform dose of 20 kg P_2O_5 (8.7 kg P)/ha on plant height, capsules per plant, seeds per capsule, test weight and seed and straw yield. It was noted that application of N increased growth and yield attributes. N at 30 kg N/ha proved optimum for pods per plant and seed yield. Regarding cultivars, it was found that Garima and Mukta (being at par) performed better than Shubhra as far as seed yield was concerned.

Chaubey and Dwivedi (1995), conducting a field experiment at Kanpur (Uttar Pradesh), studied the effect of three levels each of N, P and S applied in all possible combinations on yield and nutrient uptake of linseed cv. Garima. N was applied at 0, 40 and 80 kg N/ha, P at 0, 25 and 50 kg P_2O_5 (0, 10.9 and 21.8 kg P)/ha and S at 0, 30 and 60 kg S/ha. Application of 80 kg N, 21.8 kg P and 30 kg S/ha alone and 80 kg N+50 kg P/ha in combination proved best for seed and straw yield and N and P uptake. Further, they studied the effect of these treatments on oil content and iodine value of the oil (Dwivedi and Chaubey, 1995). Their data showed that increasing levels of N decreased and of P and S increased oil content, with the interaction 21.8 kg P x 30 kg S/ha giving the maximum value. However, a reverse trend was noted for iodine value. The interaction 80 kg N x 0 kg P/ha (also 0 kg P x 0 kg S /ha) gave the maximum iodine value.

Dutta *et al.* (1995) conducted a field experiment at Hisar (Haryana) to study the effect of five graded levels of N (0, 20, 40, 60 and 80 kg N/ha) on yield attributes of linseed cv. K 2. They observed that increasing levels of N enhanced seed yield linearly. However, N application did not affect capsules per plant and test weight. Application of 60 kg N/ha proved best for seeds per capsule.

Khare *et al.* (1995) performed a field experiment at Sagar (Madhya Pradesh) to study the effect of five graded levels of N along with a uniform basal dose of 40 kg P_2O_5 (17.5 kg P)/ha and 30 kg K_2O (24.9 kg K)/ha on the performance of two cultivars of linseed, namely J 23 and LCK 8407. Increasing levels of N increased plant height, branches per plant and straw yield. Application of N up to 90 kg N/ha enhanced seed yield. However, beyond this level, a deleterious effect was observed. Regarding cultivars, they added that J 23 gave higher seed and straw yield than LCK 8407. However, both the cultivars showed similar response in respect of plant height, primary branches, seeds per capsule, 1000-seed weight and oil content; but J 23 surpassed LCK 8407 as far as the number of capsules per plant was concerned.

Samui *et al.* (1995), carrying out a field experiment at Kalyani (West Bengal), studied the effect of three levels of N, viz. 0, 40 and 80 kg N/ha along with a uniform basal dose of 40 kg P_2O_5 (17.5 kg P) and 20 kg K_2O (16.6 kg K)/ha on the performance of six cultivars of linseed. The cultivars included Himalini, Shubhra, RLC 6, Neelum, T 397 and Neela. They observed that increasing levels of N increased plant height, yield attributes and yield. Regarding cultivar differences, they noted that cultivar Neelum exhibited the maximum value for plant height, seeds per boll, 1000-seed weight and seed yield.

Khare *et al.* (1996) conducted a field experiment at Sagar (Madhya Pradesh) to study the effect of five graded levels of N on the performance of linseed cv. R 552 under rainfed conditions. They applied five levels of N, viz. 0, 15, 30, 45 and 60 kg N/ha along with a uniform basal dose of 15 kg P_2O_5 (6.5 kg P)/ha. Increasing levels of N from 0 to 60 kg N/ha gave corresponding increase in plant height, branches per plant and capsules per plant, with 45 and 60 kg N/ha giving equal value for capsules per plant. Application of N up to 45 kg/ha increased seeds per capsule and seed and straw yield. Beyond this level, a decrease in these values was noticed. However, N did not affect the test weight.

Sharma *et al.* (1996) conducted a field experiment on two cultivars of linseed, namely DLP 21 and KL 31 at Bangalore (Karnataka). They applied four levels of N, viz. 0, 40, 80 and 120 kg N/ha. The results showed a linear relationship between N application and fibre, seed and oil yield as well as seed protein and total N uptake. However, oil content was maximum at 80 kg N/ha. Regarding cultivar differences, KL 31 proved superior to DLP 21.

Sharma *et al.* (1997), performing a field experiment at Bangalore (Karnataka), studied the effect of four levels of N, viz. 0, 40, 80 and 120 kg N/ha on the performance of two cultivars of linseed, namely DLP 21 and KL 31. They reported that increasing levels of N enhanced crop growth rate, growth and yield parameters as well as seed yield.

Singh and Verma (1997), carrying out a field experiment at Ghazipur (Uttar Pradesh), studied the effect of four levels of fertility, viz. 0 kg N+0 kg P+0 kg K/ha ($N_0P_0K_0$), $N_{30}P_{15}K_{10}$, $N_{60}P_{30}K_{20}$ and $N_{90}P_{45}K_{30}$ on the performance of linseed cv. Garima. They reported that increasing levels of fertility increased plant height, seeds per capsule and seed yield. However, fertility levels did not affect capsules per plant and 1000-seed weight.

Singh *et al.* (1997), performing a field experiment at Faizabad (Uttar Pradesh), studied the effect of four graded levels of N (0, 30, 60 and 90 kg N/ha) along with a common dose of 30 kg each of P_2O_5 (13.1 kg P) and K_2O (24.9 kg K)/ha on the performance of linseed cv. Garima. They reported that N application at increasing rates resulted in the production of superior yield and yield attributes. However, the successive doses of N up to the highest dose decreased oil content in seeds.

Kene (1997), performing a field experiment at Akola (Maharashtra), studied the effect of foliar spray of calcium dihygrogen orthophosphate, ammonium dihydrogen orthophosphate, potassium dihygrogen orthophosphate and sodium dihygrogen orthophosphate each at 1 and 2% concentration besides control and water spray, on growth and yield attributes of linseed cv. 429 grown with the recommended package of practices. It was reported that foliar feeding of linseed with 2% solution of calcium dihydrogen orthophosphate was effective in increasing seed yield and oil content, followed by 2% solution of ammonium dihydrogen orthophosphate.

Sarode *et al.* (1997, 1998) performed a field experiment on linseed cv. 429 at Akola (Maharashtra). They applied four levels of N, i.e. 0, 20, 40 and 60 kg N/ha and three levels of P, i.e. 0, 30 and 60 kg P_2O_5 (0, 13.1 and 26.2 kg P)/ha. N had a positive correlation with seed, straw and oil yield and uptake of N, P and K and a negative correlation with oil content. P fertilization, however, exhibited a positive correlation with oil content.

Singh *et al.* (1998) carried out a field experiment on the dual purpose linseed cv. Jeevan at Palampur (Himachal Pradesh). They applied two fertility levels, viz. 90 kg N + 30 kg P + 20 kg K/ha and 112.5 kg N + 37.5 kg P + 25 kg K/ha. Application of the higher fertility level enhanced fibre length, fibre content, fibre yield and retted stalk yield.

Singh and Verma (1999), conducting a field experiment at Ghazipur (Uttar Pradesh), studied the effect of five levels of N (0, 30, 60, 90 and 120 kg N/ha) on growth and yield attributes of five cultivars of linseed, namely Garima, Mukta, Neelam, Shubhra and Sweta. They reported that there was linear increase in growth and yield attributes, including plant height, primary branches per plant, capsules per plant, seeds per capsule and test weight with increasing levels of N up to 90 kg/ha. Among cultivars, Sweta surpassed the others in respect of various parameters.

Mohammad and Siddiqui (1999), performed a field experiment on four cultivars of linseed, viz. Garima, Mukta, Neelam and Shubhra at Aligarh (Uttar Pradesh) to study the effect of five graded levels of N (0, 30, 60, 90 and 120 kg N/ha) supplied with a uniform dose of 30 kg/ha each of K and P on fibre content and yield characteristics. Application of increasing levels of N up to 90 kg N / ha resulted in increased values for fibre content per plant, capsules per plant, seeds per capsule, seed yield, biological yield and oil yield. However, harvest index was affected inversely. N at 120 kg N / ha proved ineffective. A non-significant effect of N was observed on 1000-seed weight and oil percentage. Cultivar Neelam (equalled by Shubhra) proved superior to others. Interaction of 90 kg N/ha with Neelam (and Shubhra) proved best for most characters studied.

Badiyala and Sharma (2000) conducted a field experiment at Palampur (Himachal Pradesh) to study the response of linseed cv. Himalini to P and K application. P was applied at 0, 20, 40 and 60 kg P_2O_5 (0, 8.7, 17.5 and 26.2 kg P)/ha and K at 0, 20 and 40 kg K_2O (0, 16.6 and 33.2 kg K)/ha along with a uniform dose of 50 kg N/ha. The data revealed that plant height, tillers per plant, capsules per plant, seeds per capsule, 1000-seed weight and seed yield increased consistently with successive increase in P levels up to 26.2 kg P/ha. Increasing levels of K up to 33.2 kg K/ha increased all yield contributing characters, except number of tillers per plant.

Singh *et al.* (2000), conducting a field experiment at Varanasi (Uttar Pradesh), studied the effect of four levels of N (15, 30, 45 and 60 kg N /ha) along with a uniform dose of 20 kg P_2O_5 (8.7 kg P) and 20 kg K_2O (16.6 kg K) / ha on seed and straw yield, oil content and oil yield of linseed cv. Garima. Application of 45 kg N/ha gave the maximum value for all characteristics studied.

Bastia and Mohanty (2001), conducting a field experiment at Bhawanipatna (Orissa), studied the effect of four levels of N, P and K, viz. 0 kg N + 0 kg P + 0 kg K / ha, 20 kg N + 10 kg P_2O_5 (4.4 kg P) + 5 kg K_2O (4.1 kg K)/ha, 40 kg N + 20 kg P_2O_5 (8.7 kg P) + 10 kg K_2O (8.3 kg K)/ha and 60 kg N + 30 kg P_2O_5 (13.1 kg P) + 15 kg K_2O (12.4 kg K)/ha on growth and yield performance of four cultivars of linseed, namely Bhavanipatna Local, Kiran, Laxmi 27 and Pusa 3 under rainfed conditions. Application of 40 kg N + 8.7 kg P + 8.3 kg K/ha proved best for most characters, including capsules per plant and seed yield. Among cultivars, Laxmi 27, equalled by Kiran and Pusa 3, gave maximum values for most parameters studied.

Dubey (2001), conducting a field experiment at Sagar (Madhya Pradesh), studied the effect of four levels of N on dry weight per plant, plant height, branches per plant, capsules per plant, seeds per capsule, 1000-seed weight, seed yield per plant, starw yield, crop biomass and harvest index of five cultivars of linseed under rainfed conditions. The cultivars included RLC 29, SLS 7, SLS 9, SLS 21 and T 397. N was applied at 30, 40, 50 and 60 kg N/ha along with a uniform dose of 20 kg P_2O_5 (8.7 kg P)/ha. They reported that 50 kg N/ha and cultivar RLC 29 alone or in combination proved best for most of the growth and yield characteristics, including seed yield.

Kumar *et al.* (2002), carrying out a field experiment at Kanpur (Uttar Pradesh), studied the effect of four doses of N (0, 40, 80 and 120 kg N/ha) on branches per plant, capsule weight per plant, seed weight per plant and seed yield per hectare of linseed cv. Laxmi 27. It was observed that branches per plant and capsule and seed weight per plant increased with increasing rates of N up to 80 kg N /ha and beyond this dose the increase was numerical. However, seed yield of linseed was enhanced with every increment of N dose up to 120 kg N/ha.

Badiyala and Kumar (2003), working at Palampur (Himachal Pradesh), studied three levels of nutrients on growth and yield characteristics of linseed cv. Janaki. The nutrient treatments included (i) 25 kg N + 20 kg P_2O_5 (8.7 kg P) + 10 kg K_2O (8.3 kg K) /ha, (ii) 37.5 kg N + 30 kg P_2O_5 (13.1 kg P) + 15 kg K_2O (12.4 kg K) / ha and (iii) 50 kg N + 40 kg P_2O_5 (17.5 kg P) + 20 kg K_2O (16.6 kg K) / ha. They reported that increasing levels of nutrients increased plant height, primary branches per plant, capsules per plant and seed yield progressively.

2.6.3 Application of Ca and Mg

Sharma and Kamath (1990), conducting a pot experiment at New Delhi, studied the effect of three levels each of P (0, 8.8 and 17.5 mg P/kg soil) and Ca (0, 20.1 and 40.2 mg Ca/kg soil) on dry matter yield and P uptake in mustard cv. Pusa Bold. They reported that dry matter and P uptake were increased by P application up to 17.5 mg P/kg soil and by Ca application up to 20.1 mg Ca/kg soil.

Singh (1999) conducted a field experiment on mustard cv. Varuna at Mainpuri (Uttar Pradesh). They applied five levels of N (0, 40, 80, 120 and 160 kg N/ha) and three levels of S + Ca, (0 kg S + 0 kg Ca/ha), viz. S_0+Ca_0, S_{25}+Ca_{50} and S_{50}+Ca_{100}. Application of 160 kg N + 100kg Ca/ha resulted in maximum seed yield.

Bose and Mishra (2001), performing a pot experiment at Varanasi (Uttar Pradesh), studied the effect of pre-sowing seed treatment with magnesium nitrate and magnesium sulphate each at 5.0, 7.5 and 10.0 mM, along with the water-treated control, on plant height, leaf number and chlorophyll content of two cultivars of mustard, viz. Kranti and Vaibhav. The data showed that magnesium nitrate treatment particularly at 7.5 mM was more effective than the other treatments. Between cultivars, Vaibhav performed better than Kranti.

Khan *et al.* (2001) conducted a field experiments on mustard cv. Varuna at Aligarh (Uttar Pradesh) to study the effect of four basal doses of Ca, viz. 0, 20, 40 and 60 kg Ca/ha as gypsum along with 0.01 and 0.02 % pre-sowing seed soaking treatment with aqueous pyridoxine hydrochloride solution. A uniform basal dose of 90 kg N + 30 kg K/ha was also applied. They found that, 0.02 % pyridoxine treatment and 40 kg Ca/ha gave maximum values for growth and yield parameters.

2.7 Concluding Remarks

It is evident from the literature covered in the preceding pages that exogenous application of N, P and K influences the growth and development of linseed to a great extent. Moreover, not only agroclimatic conditions but also quantity, time and method of application of nutrients affect the performance considerably. It is also evident that cultivars of the crop differ in their response under a common set of conditions. The survey of literature also reveals that the information regarding the effect of GA_3 application on the performance of the crop is not available. Also, no work seems to have been done on the effect of Ca and Mg on growth and development of the crop in general and lodging due to GA_3 application in particular.

It is, therefore, highly desirable to undertake an in-depth study of the effect of different methods of application and doses and various combinations of GA_3, N, P and K on the performance of cultivars of linseed. Ca and Mg may also be included in the scheme of treatments to test their effect on the crop's performance, including lodging induced by GA_3 if any.

Materials and Methods

CONTENTS

Chapter 3

MATERIALS AND METHODS

Five pot experiments reported and discussed in the present thesis were conducted on linseed (*Linum usitatissimum* L.) during the 'rabi' (winter) seasons of 2003-2007 at the Botanical Garden of the Aligarh Muslim University, Aligarh. Materials and methods employed in the present work are given below.

3.1 Agroclimatic conditions

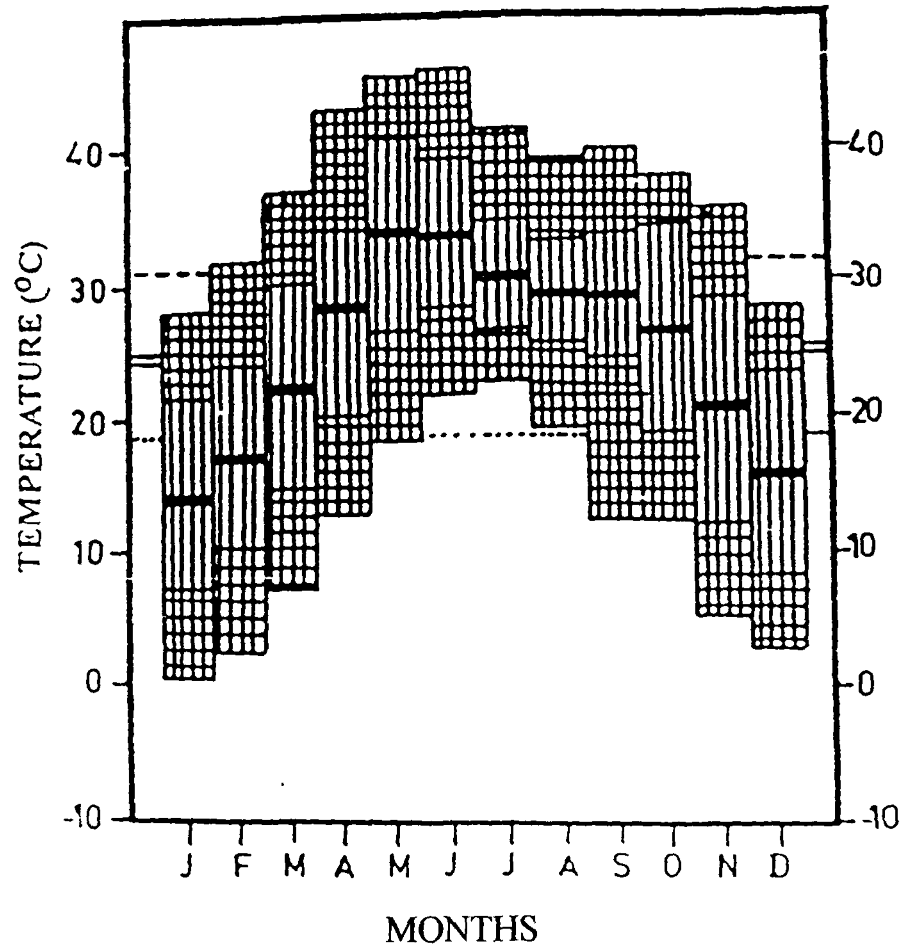
Aligarh is one of the seventy districts of Uttar Pradesh. It is situated at 27°53′ N latitude, 78°4′ E longitude and 187.45 m altitude with an area of 3431 sq km. Its climate is sub-tropical, with hot dry summers and cold winters. The winter extends from the middle of October to the end of March. The mean temperature for December and January, the coldest months, is about 15°C and 13°C respectively. The extreme minimum record for any single day is 2°C and 0.5°C respectively. The summer extends from April to the end of June and the average temperature for May is 34.5°C and for June 34°C, whereas the extreme maximum records are 45 and 45.5°C respectively (Fig. 2).

The average rainfall is 847.3 mm (Fig. 3). More than 85% of the total rainfall occurs during June to September and some 10% in the winter. The winter rainfall is useful for 'rabi' crops. Additional occasional rainfall during the summer is rare, shortened and highly variable. On an average, 4% of the total rainfall occurs during this season (Fig. 3).

The relative humidity of the winter season ranges between 56% and 77% with an average of 66.5%, that of the summer, between 37% and 49% with an average of 43% and that of the monsoon season, between 63% and 73% with an average of 68% (Fig. 4).

3.2 Soil characteristics

Soil samples collected from the homogenous mixture of soil and farmyard manure (3:1) before filling the pots were analysed for various physico-chemical properties. Experiment-wise data for soil analysis are given in Table 1.



Extreme Maximum & Minimum
Mean Daily Maximum & Minimum
Mean Monthly
Yearly Mean Maximum
Yearly Mean Temperature
Yearly Mean Minimum

Fig. 2 : Monthly temperature variation at Aligarh

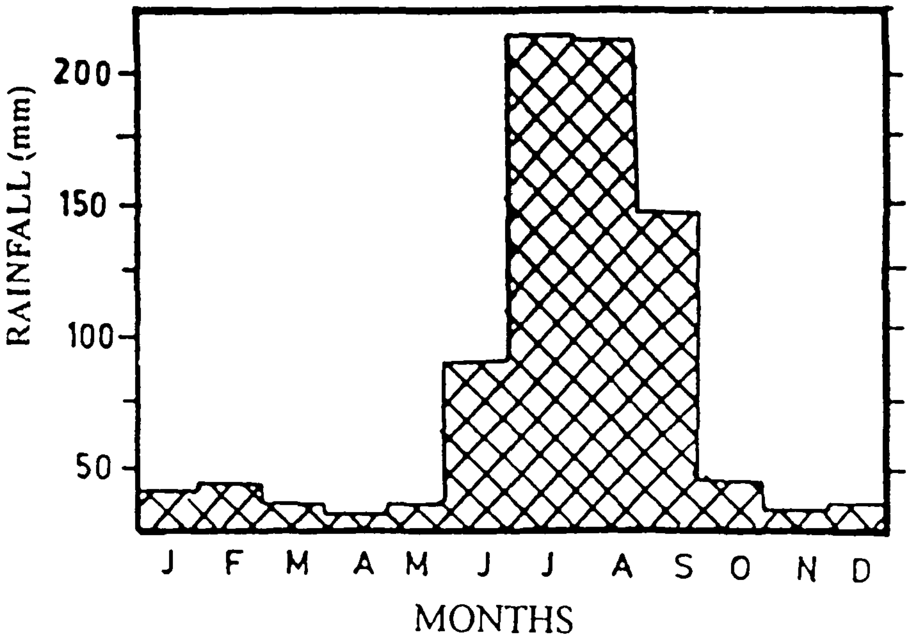


Fig. 3 : Average monthly rainfall at Aligarh

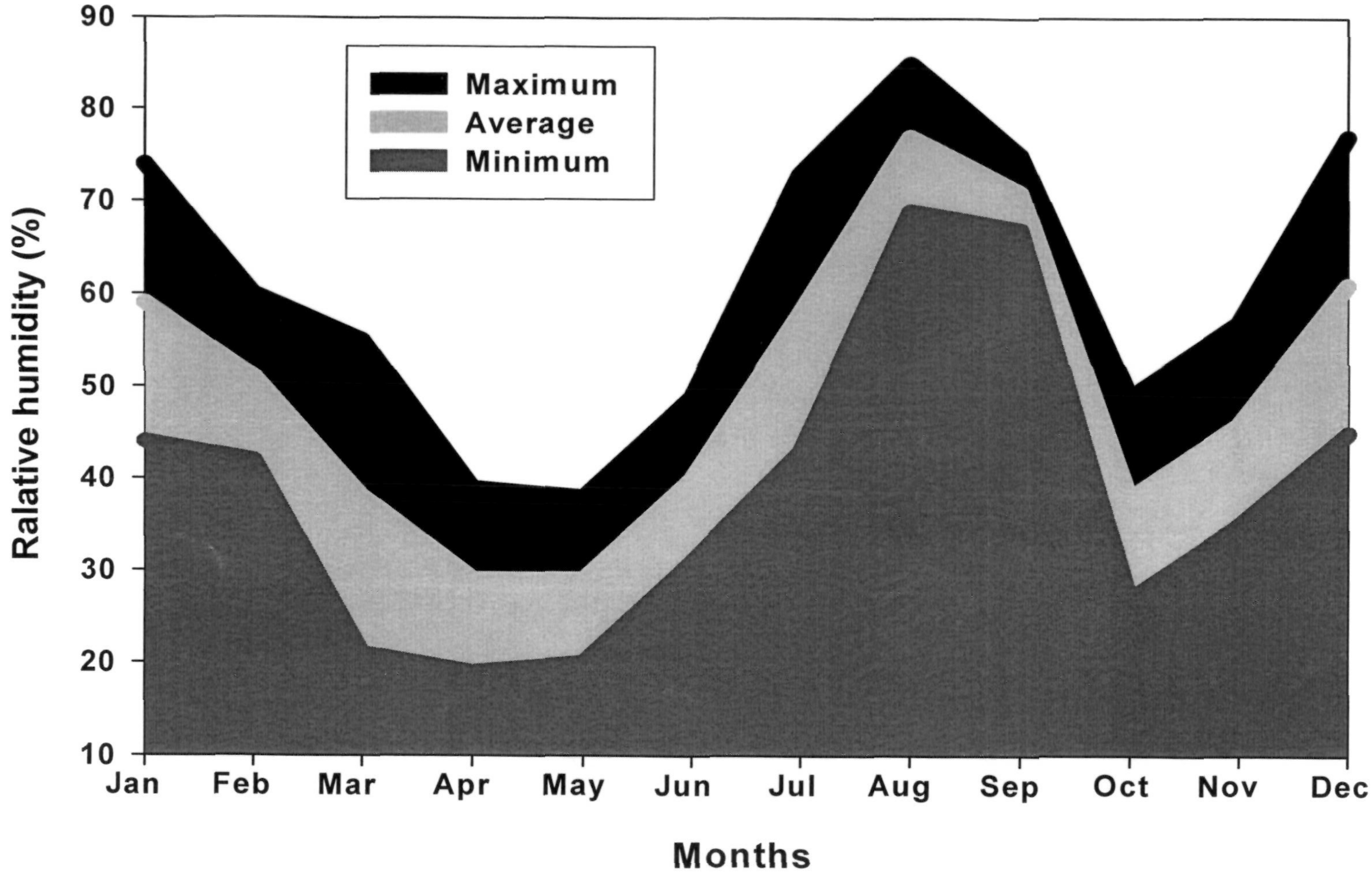


Fig. 4 : Monthly relative humidity variation at Aligarh

Table 1. Physico-chemical characteristics of the mixture of soil and farmyard manure used for Experiments 1-5

Soil characteristics	Experiments				
	1 (2003-2004)	2 (2004-2005)	3 (2005-2006)	4 (2005-2006)	5 (2006-2007)
Texture	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam
pH (1:2)	7.50	7.90	8.10	7.60	7.80
EC (1:2) (dS/m)	0.64	0.66	0.68	0.67	0.65
Available N (mg/kg soil)	84.82	98.08	95.76	95.89	97.05
Available P (mg/kg soil)	10.27	9.76	8.79	11.00	7.90
Available K (mg/kg soil)	168.08	174.78	173.04	160.89	157.02
Calcium carbonate (%)	0.07	0.09	0.08	0.12	0.11

3.3 Seeds

Authentic seeds of five newly released high yielding cultivars of linseed, namely Laxmi 27, Parvati, Rashmi, Shekhar and Shubhra, recommended for local cultivation, were obtained from the Division of Oilseed Crops of the Chandra Shekhar Azad University of Agriculture and Technology, Kanpur (Uttar Pradesh). After selecting seeds of uniform size, their viability was tested.

3.4 Pot filling

Before sowing, earthen pots of equal size (25 cm height x 25 cm diameter) were filled with the homogenous mixture of soil and farmyard manure at the ratio of 3:1 at the rate of 4 kg/pot. The required in number of pots was placed according to the design of the experiment in a net house of the Botanical Garden. One day before the sowing, pots were irrigated lightly to provide necessary moisture for germination.

Details of the five experiments are given below.

3.5 Experiment 1

The first experiment was conducted during the winter season of 2003-2004. The physico-chemical analysis of the mixture of the soil and farmyard manure used for filling the pots is given in Table 1.

This factorial randomized experiment was laid to select, the best GA_3 treatment for five newly released cultivars of linseed (*Linum usitatissimum* L.), namely Laxmi 27, Parvati, Rashmi, Shekhar and Shubhra. GA_3 treatments constituted one variant and cultivars of linseed the other. There were three GA_3 treatments, each consisting of pre-sowing seed treatment (S) followed by foliar spray (F) on plants raised from the treated seeds. Before sowing on 19 October, 2003, seeds of each of the five cultivars were soaked for 8 h in three concentrations of GA_3, viz. (i) 0 M (double distilled water, i.e. DDW), and by diluting with DDW a 10^{-2}M stock solution of GA_3 prepared by dissolving 0.346 g GA_3 in 10 ml ethyl alcohol, (ii) 10^{-8} and (iii) 10^{-6}M GA_3. For each treatment, twenty seeds were sown two cm deep in pots containing a uniform dose of fertilizer. Finally, fifteen plants in each pot were maintained. Forty DAS, plants raised from seeds treated with 0 M, 10^{-8}M and 10^{-6}M GA_3 were sprayed with 0 M, 10^{-8}M and 10^{-6}M GA_3 respectively. Thus, GA_3 treatments designated as (i) S 0M GA_3 + F 0M GA_3 (control), (ii) S 10^{-8}M GA_3 + F 10^{-8}M GA_3 and (iii) S 10^{-6}M GA_3 + F 10^{-6}M GA_3. A uniform recommended dose of 40.2 mg N, 13.4 mg P and 13.4 mg K/kg soil, equivalent to 90 kg N, 30 kg P and 30 kg K/ha (Gupta, 2004) was applied to each pot. Half of the dose of N together with full dose of P and K was applied at the time of sowing and the remaining half dose of N was added as top-dressing at 30 DAS. The sources of N, P and K were urea, diammonium phosphate and muriate of potash respectively. While calculating urea, N of diammonium phosphate was kept in mind. Each treatment was replicated four times. Summary of the experiment is given in Table 2. Standard cultural practices were adopted for growing the crop. The crop was harvested on 25 March, 2004.

3.6 Experiment 2

This experiment was conducted on three better performing cultivars of linseed, viz. Parvati, Shekhar and Shubhra (selected on the basis of the data of Experiment 1) during the winter season of 2004-2005. The physico-chemical properties of the mixture of the soil and farmyard manure used for filling the pots are given in Table 1.

This experiment was planned to test if combination (s) of basal N and P (other than that used in Experiment 1) in the presence of a uniform dose of 30 kg K/ha could improve the performance of the three cultivars of linseed grown with the best pre-sowing seed and spray treatment of GA_3 (10^{-6}M) based on the data of Experiment 1. The design of the experiment was factorial randomized. The graded combinations of N and P comprised one variant and the cultivars the other. Four levels of N and P, viz. 0 kg N + 0 kg P/ha (N_0P_0), $N_{30}P_{10}$, $N_{60}P_{20}$ and $N_{90}P_{30}$ were applied. There were four replicates for each treatment. Summary of the experiment is given in Table 3. The cultural practices including the duration of pre-sowing seed treatment and the time of foliar treatment of GA_3 and sources and method of application of nutrients were the same as in Experiment 1. The crop was sown on 16 October, 2004 and harvested on 27 March, 2005.

3.7 Experiment 3

This experiment was conducted on the three better performing cultivars of linseed (Parvati, Shekhar and Shubhra) during the winter season of 2005-2006. The physico-chemical properties of the mixture of soil and farmyard manure used for filling the pots are given in Table 1.

This experiment was laid out to test if spray of Ca could enhance further the performance of the cultivars grown with the best pre-sowing seed and spray treatment

Table 2. Summary of Experiment 1 (2003-2004)

Treatments (T) ($M\ GA_3$)		Cultivars (Cv)				
Seed	Spray	Laxmi 27	Parvati	Rashmi	Shekhar	Shubhara
0	0					
10^{-8}	10^{-8}					
10^{-6}	10^{-6}					

NB: A uniform recommended basal dose of $N_{90}P_{30}K_{30}$ was applied

Replicates : 4

Treatments : 3

Cultivars : 5

Interactions : 15

Design : Factorial randomized

Table 3. Summary of Experiment 2 (2004-2005)

Treatments (T) (kg/ha)	Cultivars (Cv)		
	Parvati	Shekhar	Shubhra
N_0P_0			
$N_{30}P_{10}$			
$N_{60}P_{20}$			
$N_{90}P_{30}$			

NB: A uniform pre-sowing seed and spray treatment of 10^{-6}M GA_3 as well as a basal dose of K_{30} was applied.

Replicates : 4

Treatments : 4

Cultivars : 3

Interactions : 12

Design : Factorial randomized

of GA_3 (10^{-6}M) and the best combination of N and P, i.e. $N_{60}P_{20}$ with K_{30} determined in Experiment 2. The levels of spray Ca constituted one variant and the cultivars the other for the factorial randomized design of the experiment. Four graded levels of spray Ca, viz. 0 kg Ca/ha (Ca_0), Ca_1, Ca_2 and Ca_3 alongwith the uniform dose of GA_3 were sprayed at 40 DAS. The source of Ca was calcium chloride. There were four replicates for each treatment. Summary of the experiment is given in Table 4. The other cultural practices including the duration of pre-sowing seed treatment and sources and method of application of other nutrients were the same as in Experiment 2. The crop was sown on 16 October, 2005 and harvested on 23 March, 2006.

3.8 Experiment 4

This experiment was performed on the three better performing cultivars of linseed (Parvati, Shekhar and Shubhra) simultaneously with Experiment 3.

In this experiment, Ca was replaced with Mg. The cultivars were grown with the best pre-sowing seed and spray treatment of GA_3 (10^{-6}M). Also, the best nutrient dose, ($N_{60}P_{20}K_{30}$) was retained. For the factorial randomized design of the experiment, the graded levels of Mg formed one factor and the cultivars the other. Four graded levels of spray Mg (0, 0.5, 1.0 and 1.5 kg Mg/ha) along with the uniform dose of GA_3 were sprayed at 40 DAS. There were four replicates for each treatment. The source of Mg was magnesium sulphate. The summary of the experiment is given in Table 5. The other cultural practices, including the duration of the pre-sowing seed treatment and sources and method of application of other nutrients, were the same as in Experiment 1. The crop was sown on 21 October, 2005 and harvested on 25 March, 2006.

3.9 Experiment 5

This experiment was conducted on the same three better performing cultivars of linseed (Parvati, Shekhar and Shubra) during the winter season of 2006-2007. The physico-chemical analysis of soil is given in Table 1.

In this factorial randomized experiment, the optimum doses of Ca determined in Experiment 3 (Ca_2) and Mg established in Experiment 4 ($Mg_{0.5}$) were sprayed together on the cultivars grown with the best pre-sowing seed and spray treatment (10^{-6}M GA_3) and nutrient dose ($N_{60}P_{20}K_{30}$) to test their efficacy in combination.

Table 4. Summary of Experiment 3 (2005-2006)

Treatments (T) (kg/ha)	Cultivars (Cv)		
	Parvati	Shekhar	Shubhra
Ca_0			
Ca_1			
Ca_2			
Ca_3			

NB: A uniform pre-sowing seed and foliar treatment of $10^{-6}M$ GA_3 as well as a basal dose of $N_{60}P_{20}K_{30}$ was applied.

Replicates : 4

Treatments : 4

Cultivars : 3

Interactions : 12

Design : Factorial randomized

Table 5. Summary of Experiment 4 (2005-2006)

Treatments (T) (kg/ha)	Cultivars (Cv)		
	Parvati	Shekhar	Shubhra
Mg_0			
$Mg_{0.5}$			
$Mg_{1.0}$			
$Mg_{1.5}$			

NB: A uniform pre-sowing seed and foliar treatment of 10^{-6}M GA_3 as well as a basal dose of $N_{60}P_{20}K_{30}$ was applied.

Replicates : 4

Treatments : 4

Cultivars : 3

Interactions : 12

Design : Factorial randomized

Spray treatments constituted one variant and cultivars the other. There were four spray treatments, viz. (i) 0 kg Ca + 0 kg Mg/ha (Ca_0Mg_0), (ii) Ca_2Mg_0, (iii) $Ca_0Mg_{0.5}$ and (iv) $Ca_2Mg_{0.5}$. Spray treatments were applied at 40 DAS. There were four replicates for each treatment. The scheme of the experiment is given in Table 6. The other cultural practices including the duration of the pre-sowing seed treatment and sources and method of application of the other nutrients were the same as in Experiment 1. The crop was sown on 23 October, 2006 and harvested on 26 March, 2007.

3.10 Sampling techniques

Three plants from each replicate were uprooted randomly at the sampling stage in all experiments. Growth characteristics and physiological and biochemical parameters were studied at 60 and 75 DAS and yield and quality characteristics at harvest. Details of parameters studied are given below.

3.10.1 Growth characteristics

To study the growth performance of the crop, the following characteristics were studied:

1. Height per plant
2. Leaf area per plant
3. Leaf area index
4. Fresh weight per plant
5. Dry weight per plant

3.10.1.1 Computation of leaf area per plant

Leaf area per plant was determined by gravimetric method. The area of twenty leaves from each of the three plants was calculated by tracing on a graph sheet and dry weight of the twenty leaves was also recorded. The leaf area per plant was calculated by putting the values for leaf dry weight per plant and dry weight of the twenty leaves in the following formula:

$$\text{Leaf area} = \frac{LA_1 \times W_2}{W_1}$$

where,

LA_1 = leaf area of twenty leaves tracing on the graph paper

W_1 = dry weight of twenty leaves for which the area was traced on the graph paper

W_2 = dry weight of total leaves per plant

Table 6. Summary of Experiment 5 (2006-2007)

Treatments (T) (kg/ha)	Cultivars (Cv)		
	Parvati	Shekhar	Shubhra
Ca_0Mg_0			
$Ca_2 Mg_0$			
$Ca_0Mg_{0\ 5}$			
$Ca_2Mg_{0\ 5}$			

NB: A uniform pre-sowing seed and foliar treatment of 10^{-6}M GA_3 as well as a basal dose of $N_{60}P_{20}K_{30}$ was applied.

Replicates : 4

Treatments : 4

Cultivars : 3

Interactions : 12

Design : Factorial randomised

3.10.1.2 Determination of leaf area index

Leaf area index was determined by using the formula proposed by Watson (1958).

$$\text{Leaf area index} = \frac{\text{Leaf area}}{\text{Ground area}}$$

3.10.2 Physiological and biochemical parameters

The following physiological and biochemical parameters were studied:

1. Net photosynthetic rate (P_N)
2. Carbonic anhydrase (CA) activity
3. Leaf chlorophyll content
4. Leaf N, P, K, Ca and Mg content

3.10.2.1 Determination of net photosynthetic rate

This parameter was measured in cloudless clear days between 11.00 am and 1.00 pm in fully expanded leaves of plants with the help of a portable photosynthesis system (LiCOR, 6200 Lincoln, USA). Care was taken to use leaves of the same age for the measurement.

3.10.2.2 Measurement of CA activity

The enzyme activity was measured in fresh leaves collected randomly from each replicate at the same growth stage as those selected for growth characteristics. The enzyme CA is responsible for the catalysis of the reversible hydration of carbon dioxide to give the bicarbonate ion (HCO_3^-).

$$H_2O + CO_2 \overset{CA}{\rightleftharpoons} H^+ + HCO_3^-$$

The activity of the enzyme was estimated by adopting the method of Dwivedi and Randhawa (1974).

Leaves were collected randomly from each replicate and cut into small pieces (1 cm^2) at a temperature below 20°C. After mixing them, 200 mg leaf pieces were weighed and cut further into smaller pieces keeping them in 10 ml 0.2 M aqueous cystein hydrochloride solution (Appendix) in a petridish at 0 to 4°C for 20 min. The solution adhering on their surface was then removed with the help of a blotting paper. This was followed by transfer immediately to a test tube having 4 ml phosphate buffer of pH 6.8 (Appendix). To this, 4 ml 0.2 M sodium bicarbonate (in 0.2 M sodium hydroxide solution) and 0.2 ml of 0.002% bromothymol blue indicator (Appendix) were added. After shaking, the tubes were kept at 0-4°C for 20 min. Carbon dioxide liberated during catalytic action of the enzyme on sodium bicarbonate was estimated by titrating the reaction mixture against 0.05 N hydrochloric acid (Appendix), using methyl red as an internal indicator. A control reaction mixture was also titrated against 0.05 N hydrochloric acid. The difference of the sample reading and blank reading was noted for further calculation of enzyme activity.

The activity of the enzyme was calculated by the following formula:

$$\frac{0.5 \times V \times N}{W \times T} \text{ m mol } (CO_2)\text{/mg (leaf fresh mass)/min}$$

where,

V = difference in volume (ml) of hydrochloric acid used in the blank and sample mixture

N = normality of hydrochloric acid

W = weight of leaves (mg) used

T = duration of the catalytic action of the enzyme (min)

The activity of the enzyme was expressed in μmol (CO_2)/kg (leaf fresh mass)/s.

3.10.2.3 Estimation of leaf chlorophyll content

The method of Arnon (1949) was used for the estimation of chlorophyll content. The details are given below.

1 g fresh leaves from each replicate were homogenized in sufficient quantity of 80% acetone (Appendix) using a mortar and pestle. The extract was filtered through Whatman No 42 filter paper and the filtrate was collected in a 100 ml volumetric flask. The process was repeated three times and each time the filtrate was collected in the same volumetric flask. Finally, the volume was made up to 100 ml with 80% acetone. 5 ml extract from the 100 ml volumetric flask was transferred to a 50 ml volumetric flask and the volume was made up to the mark with 80% acetone. 5 ml sample of chlorophyll extract from the 50 ml volumetric flask was transferred to a cuvette and the optical density (OD) was read at 645 and 663 nm on a spectrophotometer (Spectronic 20D, Milton Roy, USA).

The total chlorophyll content in fresh leaves was calculated using the following formula:

$$\text{Total chlorophyll} = [(20.2 \times \text{OD } 645) + 8.02 \times \text{OD } 663)] \times \frac{V \times W}{1000}$$

where,

V = volume of the extract in ml

W = weight of the fresh leaves used for the extraction of the pigment in g

3.10.2.4 Estimation of leaf N, P, K, Ca and Mg content

The sampled plants were dried in an oven at 80°C for 24 h. The dried leaves from each sample were finally powdered and then passed through a 72-mesh screen. For the estimation of these nutrients the leaf powder was first digested according to the standard technique described below.

3.10.2.4.1 Digestion

100 mg oven-dried powder of leaf material was transferred to a digestion tube to which 2 ml sulphuric acid was added. The tube was then kept on a digestion assembly at 80°C for about 2 h to allow the complete reduction of nitrates present in the plant material by the organic matter itself. Initially, dense white fumes were given off and then the content of the tube turned black. After cooling the tube for about 15 min, 0.5 ml 30% hydrogen peroxide was added drop by drop and the tube was heated again till the colour of the solution changed from black to light yellow. The digestion tube was cooled for 10 min and an additional amount (2-3 drops) of 30% hydrogen peroxide was added followed by gentle heating for about 15 min to get a clear and colourless solution. At this stage, care was taken in the addition of hydrogen peroxide because its excess might oxidize ammonia in the absence of organic matter. The peroxide digested material was diluted with DDW and transferred with three washings to a 100 ml volumetric flask and finally the volume was made up to the mark with DDW. The details of methods employed for the estimation of N, P, K, Ca and Mg are given below.

3.10.2.4.2 Estimation of N

N was estimated according to the method of Lindner (1944).

A 10 ml aliquot of the sulphuric acid-peroxide digested material was taken in a 50 ml volumetric flask and the excess of the acid was neutralized by the addition of

2 ml of 2.5 N sodium hydroxide (Appendix). 1 ml of 10% sodium silicate (Appendix) was added to prevent turbidity and finally, the volume was made up with DDW.

A 5 ml aliquot of this solution was taken in a 10 ml graduated test tube and 0.5 ml Nessler's reagent (Appendix) was added dropwise mixing it thoroughly after each addition. The contents of the test tube were allowed to stand for about 5 min for maximum colour development. The solution was transferred to a colorimetric tube and OD was read on the spectrophotometer at 525 nm. A blank was run with each set. The reading of each sample was compared with standard calibration curve and N content was computed in terms of percentage on dry weight basis.

3.10.2.4.2.1 Standard calibration curve

50 mg ammonium sulphate was dissolved in 100 ml DDW and the final volume was made 1 l with DDW. From this stock solution, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9 and 1.0 ml aliquots were pipetted to ten different test tubes. The solution in each test tube was diluted to 5 ml with DDW. In each test tube, 0.5 ml Nessler's reagent was added. After 5 min, the solution was transferred to a colorimetric tube and OD was read on the spectrophotometer at 525 nm. A blank was run with each set. A curve was plotted for various concentrations of ammonium sulphate solution versus OD.

3.10.2.4.3 Estimation of P

The method of Fiske and Subba Row (1925) was adopted to estimate the total P in the digested material.

A 5 ml aliquot of the sulphuric acid-peroxide digested material was taken in a 10 ml graduated test tube and 1 ml molybdic acid (Appendix) was carefully added followed by the addition of 0.4 ml 1-amino-2-naphthol-4-sulphonic acid (Appendix). The colour of the solution turned blue. The final volume in the tubes was made up to 10 ml with DDW. The contents of the tube were allowed to stand for 5 min after mixing thoroughly. They were then transferred to a colorimetric tube and OD was read at 620 nm on the spectrophotometer. A blank was run simultaneously for each determination. The reading of each sample was compared with the standard calibration curve and P content was computed in terms of percentage on dry weight basis.

3.10.2.4.3.1 Standard calibration curve

0.351 g potassium dihydrogen orthophosphate was dissolved in 100 ml DDW followed by the addition of 10 ml 10 N sulphuric acid. The final volume was made up to 1 l with DDW.

From this stock solution, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9 and 1.0 ml aliquots were taken in separate test tubes. 1 ml molybdic acid and 0.4 ml 1-amino-2-naphthol-4-sulphonic acid were added in each test tube. The final volume in each test tube was made up to 10 ml with DDW. After 5 min, OD of the developed colour was read at 620 nm on the spectrophotometer. A blank was run with each set of determination. A curve was plotted for various concentrations of potassium dihydrogen orthophosphate solution versus OD.

3.10.2.4.4 Estimation of K

It was estimated flame photometrically. A 10 ml aliquot of the sulphuric acid-peroxide digested material was taken and it was read on a flame photometer (AIMIL "Fotoflame") using the filter for potassium. A blank was run side by side. The readings were compared with the calibration curve plotted for different dilutions of a standard potassium chloride solution and the content was computed in terms of percentage on dry weight basis.

3.10.2.4.4.1 Standard calibration curve

1.907 g potassium chloride was dissolved in 50 ml DDW followed by dilution to 100 ml. 1 ml of this solution, was diluted to 1 l. The resultant solution would contain 10 ppm K, from which 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10 ml aliquots were transferred to 10 different vials. The solution in each vial was diluted to 10 ml. The diluted solution of each vial was run separately. A blank was run with each set of determination. Standard curve was prepared for different dilutions of potassium chloride solution versus readings on the scale of the galvanometer.

3.10.2.4.5 Estimation of Ca

It was also estimated flame photometrically. After adjusting the filter for Ca, 10 ml sulphuric acid-peroxide digested material was run. A blank was also run side by side. A standard curve, taking known dilutions of a standard calcium carbonate solution, was plotted. The reading of each sample was compared with this calibration curve and Ca content was expressed in terms of percentage on dry weight basis.

3.10.2.4.5.1 Standard calibration curve

2.5 g calcium carbonate was dissolved in 100 ml DDW followed by addition of 5 ml hydrochloric acid drop by drop. This solution was heated for about 20 min to expell carbon dioxide. After obtaining a clear solution, the final volume was made up to 1 l with DDW. Thus, a stock solution of 1000 ppm Ca was obtained. From this stock solution, aliquots containing 10, 20, 30, 40 and 50 ppm Ca were prepared and run in the flame photometer separately. A blank was also run with each set of determination. A calibration curve was plotted in the same way as for K.

3.10.2.4.6 Estimation of Mg

Mg content was estimated by determining the content of both Ca and Mg according to Hesse (1971). A 5 ml sulphuric acid-peroxide digested aliquot was diluted to 10 ml. To this solution, 15 ml ammonium chloride–ammonium hydroxide buffer of pH 10 (Appendix) was added followed by addition of 10 drops each of 1% potassium cyanide, 5% hydroxylamine-hydrochloride, 4% potassium hexacyanoferrate (II) and triethanolamine (Appendix) with stirring. After adding 10 drops of eriochrome black T indicator, the mixture was titrated against 0.01N ethylene diamine tetraacetic acid (EDTA). A control reaction mixture was also titrated against 0.01N EDTA. Volume of EDTA used in the titration of each sample was noted. By using the following formula, the total content of both Ca and Mg was calculated:

$$\text{Total content of Ca and Mg} = \frac{R \times N \times 1000}{V}$$

where,

R = volume of EDTA used in titration (ml)

V = volume of the aliquot taken (ml)

N = normality of EDTA

Mg content was determined by subtracting the value for Ca determined earlier separately from that for both Ca and Mg.

3.10.3 Yield and quality characteristics

The following characteristics were studied at harvest:

1. Capsules per plant
2. Seeds per capsule
3. 1000-seed weight

4. Seed yield per plant
5. Biological yield per plant
6. Harvest index
7. Oil content
8. Oil yield per plant
9. Iodine value
10. Fibre yield per plant
11. Lodging

To study capsules per plant and seeds per capsule, one plant from each pot was taken randomly. For other yield characteristics all nine plants of each pot were taken into consideration.

3.10.3.1 Harvest index

The proportion of the biological yield representing the economic yield is called harvest index. Harvest index was calculated by the following formula:

$$\text{Harvest index} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

3.10.3.2 Determination of oil content

The procedure for assessing the oil content of seeds is described below.

3.10.3.2.1 Preparation of seed sample

To remove impurities smaller than the seeds, a sieve having a pore size smaller than the size of seeds was used. The impurities larger than the seeds were removed using a sieve with a pore size just larger than the seeds.

3.10.3.2.2 Grinding of seed sample

After getting pure seeds, seed samples were crushed to get a fine meal for extracting the oil.

3.10.3.2.3 Extraction of oil

To assess the oil content of seeds, 25 g fine meal of seeds was weighed and transferred to the flask of a Soxhlet apparatus to which sufficient quantity of pure petroleum ether was added. The apparatus was kept on a water bath, running at 60°C, for about 6 h. At the end of the extraction process, the petroleum extract of seeds was left in the air to evaporate the petroleum ether from it. The oil left after the evaporation of petroleum ether was weighed and expressed as percentage of the mass of the seeds by the following formula:

$$\text{Percentage of oil} = \frac{m \times 100}{m_0}$$

where,

m mass of oil in g

m_0 mass of seed sample in g

3.10.3.3 Determination of oil yield

The oil yield was computed on the basis of oil percentage and seed yield.

3.10.3.4 Determination of iodine value

The quality of the oil was assessed in terms of iodine value. The iodine value of the oil is the number of gram of iodine absorbed by 100 g of oil and expressed as the weight of iodine. It was determined by using iodine monochloride method (Anonymous, 1970) as described below.

2 g accurately weighed oil was placed in a dry ground neck flask to which 10 ml carbon tetrachloride and 20 ml iodine monochloride solution (Appendix) were added. The flask was stoppered and was allowed to stand in the dark for about 30 min. After 30 min, 15 ml potassium iodide solution (Appendix) and 100 ml DDW were poured into it with proper shaking. Titration was carried out with 0.1 N sodium thiosulphate solution (Appendix), using starch solution as an indicator. Number of ml 'a' of sodium thiosulphate solution used was noted. A similar operation was done but without oil and number of ml 'b' of 0.1 N sodium thiosulphate solution was noted. Iodine value was calculated by the following formula:

$$\text{Iodine value} = \frac{(b-a) \times 0.01269 \times 100}{W}$$

where,

a and b number of ml of 0.1 N sodium thiosulphate solution used in sample and blank titration respectively

W weight of oil in g.

3.10.5 Statistical analysis

All data were analyzed statistically adopting the analysis of variance technique, according to Gomez and Gomez (1984). In applying the F test, the error due to replicates was also determined. When 'F' value was found to be significant at 5% level of probability, critical difference (CD) was calculated. The models of analysis of variance for the designs employed are given in Table 7.

Table 7. Models of the analysis of variance

Experiment 1 (Factorial randomized design)

Source of variation	DF	SS	MSS	F
Replicates	3			
Treatments (T)	2			
Cultivars (Cv)	4			
T × Cv	8			
Error	42			
Total	59			

Experiments 2-5 (Factorial randomized design)

Source of variation	DF	SS	MSS	F
Replicates	3			
Treatments (T)	3			
Cultivars (Cv)	2			
T × Cv	6			
Error	33			
Total	47			

Experimental Results

CONTENTS

Chapter 4

EXPERIMENTAL RESULTS

The important results of the experiments (Tables 8-101) as detailed in the preceding chapter are described briefly in this chapter.

4.1 Experiment 1

This factorial randomized pot experiment was planned to determine the best pre-sowing seed and foliar treatment of GA_3 in the presence of recommended basal dose of N, P and K for five linseed cultivars. The performance of the crop was studied in terms of the growth characteristics and physiological and biochemical parameters studied at 60 and 75 DAS and yield and quality characteristics at harvest (Tables 8-25).

4.1.1 Growth characteristics

The effect of GA_3 treatment and their interactions with cultivars on all growth characteristics as also cultivar differences were significant at both stages (Tables 8-12).

4.1.1.1 Height per plant

The pre-sowing seed and foliar treatment at 10^{-6}M GA_3 gave maximum value at both stages. Its effect was followed by that of 10^{-8}M GA_3 at 60 DAS but equalled by that of the same treatment (10^{-8}M GA_3) at 75 DAS. Application of GA_3 at 10^{-6}M resulted in 14.9 and 16.3% higher value at 60 and 75 DAS respectively than the water treatment (0 M GA_3).

Among cultivars, Shubhra performed best at both stages. However, it was equalled by Parvati at 60 DAS and also by Shekhar at 75 DAS. Shubhra gave 24.8 and 18.9% higher value at 60 and 75 DAS respectively than Laxmi 27 which gave the lowest value.

Of interactions, 10^{-6}M GA_3 x Shubhra proved best at both stages. Its effect was at par with that of 10^{-6}M GA_3 x Parvati and 10^{-8}M GA_3 x Shubhra at 60 DAS but followed by that of 10^{-8}M GA_3 x Shubhra at 75 DAS. Interaction 10^{-6}M GA_3 x Shubhra gave 42.2 and 49.8% higher value at 60 and 75 DAS respectively than 0M GA_3 x Laxmi 27 which gave the lowest value (Table 8).

Table 8. Effect of pre-sowing seed treatment and foliar application of GA_3 on height per plant (cm) of linseed cultivars at two stages of growth (Mean of four replicates)

Treatments (T) ($M\ GA_3$)		Cultivars (Cv)					Mean
Seed	Spray	Laxmi 27	Parvati	Rashmi	Shekhar	Shubhra	
				60 DAS			
0	0	46.5	55.0	49.2	51.7	59.3	52.3
10^{-8}	10^{-8}	51.8	61.2	54.3	56.9	63.3	57.5
10^{-6}	10^{-6}	52.9	64.7	56.8	59.9	66.1	60.1
Mean		50.4	60.3	53.4	56.2	62.9	
CD at 5%		T = 1.99		Cv = 2.57		T x Cv = 4.46	
				75 DAS			
0	0	58.8	65.5	61.4	64.7	68.4	63.8
10^{-8}	10^{-8}	64.7	72.5	67.5	71.2	77.1	70.6
10^{-6}	10^{-6}	67.0	77.0	70.8	74.9	81.1	74.2
Mean		63.5	71.7	66.6	70.3	75.5	
CD at 5%		T = 3.99		Cv = 5.16		T x Cv = 8.93	

NB : A uniform recommended basal dose of $N_{90}P_{30}K_{30}$ was applied.

4.1.1.2 Leaf area per plant

Increasing levels of pre-sowing seed and foliar treatment of GA_3 increased leaf area per plant linearly at both stages. Application of 10^{-6}M GA_3 gave 14.3 and 11.1% higher value at 60 and 75 DAS respectively than the water treatment.

Regarding cultivar differences, Shubhra, followed by Parvati, gave maximum value at both growth stages. Shubhra gave 24.7 and 29.7% higher value at 60 and 75 DAS respectively than Rashmi which gave the lowest value. Moreover, Shubhra surpassed Laxmi 27 by 16.3 and 26.8% at respective stages.

Interaction 10^{-6}M GA_3 x Shubhra proved best. Its effect was followed by that of 10^{-8}M GA_3 x Shubhra and 10^{-6}M GA_3 x Parvati at each stage. Interaction 10^{-6}M GA_3 x Shubhra gave 43.1 and 45.0% higher value at 60 and 75 DAS respectively than 0 M GA_3 x Rashmi which gave the lowest value. Moreover, 10^{-6}M GA_3 x Shubhra increased leaf area by 33.0 and 41.2% over 0 M GA_3 x Laxmi 27 at respective stages (Table 9).

4.1.1.3 Leaf area index

The pre-sowing seed and foliar treatment at 10^{-6}M GA_3 gave the maximum value at both stages. However, its effect was followed by that of 10^{-8}M GA_3 at each stage. Application of 10^{-6}M GA_3 gave 14.3 and 11.1% higher value at 60 and 75 DAS respectively than the water treatment.

Cultivar Shubhra, followed by Parvati, proved best at each stage. Shubhra gave 24.6 and 29.7% higher value at 60 and 75 DAS respectively than Rashmi which gave the lowest value. Moreover, Shubhra surpassed Laxmi 27 by 16.4 and 26.7% at respective stage.

Interaction 10^{-6}M GA_3 x Shubhra, followed by 10^{-8}M GA_3 x Shubhra and 10^{-6}M GA_3 x Parvati, gave the maximum value at both stages. Interaction 10^{-6}M GA_3 x Shubhra gave 43.2 and 45.0% higher value at 60 and 75 DAS respectively than 0 M GA_3 x Rashmi which gave the lowest value (Table 10). Moreover, 10^{-6}M GA_3 x Shubhra increased leaf area index by 33.2 and 41.2% over 0 M GA_3 x Laxmi 27 at respective stage (Table 10).

Table 9. Effect of pre-sowing seed treatment and foliar application of GA_3 on leaf area per plant (cm^2) of linseed cultivars at two stages of growth (Mean of four replicates)

Treatments (T) (M GA_3)		Cultivars (Cv)					Mean
Seed	Spray	Laxmi 27	Parvati	Rashmi	Shekhar	Shubhra	
				60 DAS			
0	0	159.88	176.73	148.55	168.14	179.92	166.64
10^{-8}	10^{-8}	169.93	189.20	156.50	179.50	198.61	178.75
10^{-6}	10^{-6}	178.63	202.70	169.20	189.00	212.70	190.45
Mean		169.48	189.54	158.08	178.88	197.08	
CD at 5%		T = 3.75		Cv = 4.84		T x Cv = 8.39	
				75 DAS			
0	0	260.78	304.63	253.93	276.40	318.60	282.87
10^{-8}	10^{-8}	271.15	323.00	264.13	291.00	343.85	298.63
10^{-6}	10^{-6}	280.83	341.75	276.45	303.57	368.30	314.18
Mean		270.92	323.13	264.84	290.32	343.58	
CD at 5%		T = 5.35		Cv = 6.91		T x Cv = 11.97	

NB : A uniform recommended basal dose of $N_{90}P_{30}K_{30}$ was applied.

Table 10. Effect of pre-sowing seed treatment and foliar application of GA_3 on leaf area index of linseed cultivars at two stages of growth (Mean of four replicates)

Treatments (T) (M GA_3)		Cultivars (Cv)					Mean
Seed	Spray	Laxmi 27	Parvati	Rashmi	Shekhar	Shubhra	
				60 DAS			
0	0	4.88	5.40	4.54	5.14	5.50	5.09
10^{-8}	10^{-8}	5.19	5.78	4.78	5.48	6.07	5.46
10^{-6}	10^{-6}	5.46	6.19	5.17	5.77	6.50	5.82
Mean		5.17	5.79	4.83	5.46	6.02	
CD at 5%		T = 0.10		Cv = 0.13		T x Cv = 0.23	
				75 DAS			
0	0	7.97	9.31	7.76	8.44	9.73	8.64
10^{-8}	10^{-8}	8.28	9.87	8.06	8.89	10.50	9.12
10^{-6}	10^{-6}	8.58	10.44	8.44	9.27	11.25	9.60
Mean		8.28	9.87	8.09	8.87	10.49	
CD at 5%		T = 0.21		Cv = 0.27		T x Cv = 0.47	

NB : A uniform recommended basal dose of $N_{90}P_{30}K_{30}$ was applied.

4.1.1.4 Fresh weight per plant

Increasing levels of pre-sowing seed and foliar treatment of GA_3 increased fresh weight per plant linearly at both sampling stages. Application of GA_3 at 10^{-6}M enhanced fresh weight per plant by 51.4 and 42.4% at 60 and 75 DAS respectively over the water treatment.

Cultivar Shubhra, equalled by Shekhar, performed best at both stages. Shubhra gave 34.3 and 45.9% higher value at 60 and 75 DAS respectively than Laxmi 27 which gave the lowest value.

Interaction 10^{-6}M GA_3 x Shubhra, equalled by 10^{-6}M GA_3 x Shekhar, proved best at both stages. Interaction 10^{-6}M GA_3 x Shubhra gave 102.7 and 101.3% higher value at 60 and 75 DAS respectively than 0M GA_3 x Laxmi 27 which gave lowest value (Table 11).

4.1.1.5 Dry weight per plant

Increasing levels of GA_3 treatment enhanced this parameter linearly at both stages. Application of 10^{-6}M GA_3 gave 45.5 and 40.5% more dry matter at 60 and 75 DAS respectively than the water treatment.

Among cultivars, Shubhra surpassed others at each stage. It was followed by Parvati at 60 DAS and Shekhar at 75 DAS. Shubhra produced 58.6 and 65.2% higher dry weight per plant at 60 and 75 DAS respectively than Laxmi 27 which gave the lowest value.

Among interactions, 10^{-6}M GA_3 x Shubhra proved best at each stage. Its effect was followed by that of interaction 10^{-8}M GA_3 x Shubhra at 60 DAS but equalled by that of the same interaction at 75 DAS. Interaction 10^{-6}M GA_3 x Shubhra gave 126.2 and 131.6% higher value at 60 and 75 DAS respectively than 0 M GA_3 x Laxmi 27 which gave the lowest value (Table 12).

4.1.2 Physiological and biochemical parameters

The differences of treatment effect and cultivars, alone as well as in combination, for all physiological and biochemical parameters studied at both stages were significant, except leaf N, P and K content at 60 DAS. However, the non-significant effect of treatments on leaf N, P and K content, cultivar differences for P content and interaction effect on leaf K content at 75 DAS were observed (Tables 13-18).

Table 11. Effect of pre-sowing seed treatment and foliar application of GA_3 on fresh weight per plant (g) of linseed cultivars at two stages of growth (Mean of four replicates)

Treatments (T) (M GA_3)		Cultivars (Cv)					Mean
Seed	Spray	Laxmi 27	Parvati	Rashmi	Shekhar	Shubhra	
				60 DAS			
0	0	10.16	11.98	10.64	12.29	12.14	11.44
10^{-8}	10^{-8}	12.41	14.99	12.94	15.65	16.53	14.50
10^{-6}	10^{-6}	14.12	17.14	15.13	19.64	20.59	17.32
Mean		12.23	14.70	12.90	15.86	16.42	
CD at 5%		T = 1.09		Cv = 1.40		T x Cv = 2.43	
				75 DAS			
0	0	15.96	17.24	14.78	19.97	20.26	17.64
10^{-8}	10^{-8}	18.17	20.87	17.59	24.76	26.57	21.59
10^{-6}	10^{-6}	20.00	23.76	19.82	29.91	32.13	25.12
Mean		18.04	20.62	17.40	24.88	26.32	
CD at 5%		T = 1.11		Cv = 1.44		T x Cv = 2.49	

NB : A uniform recommended basal dose of $N_{90}P_{30}K_{30}$ was applied.

Table 12. Effect of pre-sowing seed treatment and foliar application of GA_3 on dry weight per plant (g) of linseed cultivars at two stages of growth (Mean of four replicates)

Treatments (T) (M GA_3)		Cultivars (Cv)					Mean
Seed	Spray	Laxmi 27	Parvati	Rashmi	Shekhar	Shubhra	
				60 DAS			
0	0	2.20	2.98	2.61	2.70	3.32	2.76
10^{-8}	10^{-8}	2.68	4.02	3.22	3.36	4.50	3.55
10^{-6}	10^{-6}	3.11	4.62	3.79	4.21	5.13	4.17
Mean		2.66	3.87	3.21	3.42	4.32	
CD at 5%		T = 0.22		Cv = 0.28		T x Cv = 0.49	
				75 DAS			
0	0	3.00	4.16	3.46	4.98	5.25	4.17
10^{-8}	10^{-8}	3.67	5.29	4.42	6.32	6.98	5.34
10^{-6}	10^{-6}	4.69	6.61	5.50	8.44	9.42	6.93
Mean		3.78	5.35	4.46	6.58	7.22	
CD at 5%		T = 0.34		Cv = 0.43		T x Cv = 0.75	

NB : A uniform recommended basal dose of $N_{90}P_{30}K_{30}$ was applied.

4.1.2.1 Net photosynthetic rate

A linear increase in P_N was recorded with increasing levels of GA_3 at both the stages. GA_3 at 10^{-6}M improved P_N by 13.0 and 12.2% at 60 and 75 DAS respectively over the water treatment.

Regarding cultivar differences, Shubhra proved best. However, it was equalled by Parvati and Shekhar at each stage. Shubhra exhibited 13.4 and 13.8% higher P_N at 60 and 75 DAS respectively than Laxmi 27 which gave the lowest value.

Interaction 10^{-6}M GA_3 x Shubhra gave the maximum value at each stage. However, its effect was equalled by that of 10^{-6}M GA_3 x Parvati (and Shekhar) at both stages and also that of 10^{-6}M GA_3 x Rashmi at 75 DAS. Interaction 10^{-6}M GA_3 x Shubhra improved P_N by 27.4 and 27.2% at 60 and 75 DAS respectively than 0 M GA_3 x Laxmi 27 which gave the lowest value (Table 13).

4.1.2.2 Carbonic anhydrase activity

Treatment 10^{-6}M GA_3 proved superior for this parameter at both stages. Its effect was followed by that of 10^{-8}M GA_3 at each stage. Treatment 10^{-6}M GA_3 increased CA activity by 9.0 and 14.0% at 60 and 75 DAS respectively than the water treatment.

Among cultivars, Shubhra followed by Parvati performed best at both sampling stages. Shubhra exhibited 11.1 and 17.2% higher activity at 60 and 75 DAS respectively than Laxmi 27 which gave the lowest value.

Interaction 10^{-6}M GA_3 x Shubhra gave the maximum value at both stages. Its effect was followed by that of 10^{-8}M GA_3 x Shubhra, 10^{-6}M GA_3 x Parvati and 10^{-8}M GA_3 x Parvati at 60 DAS and that of 10^{-8}M GA_3 x Shubhra, 10^{-6}M GA_3 x Parvati and 10^{-6}M GA_3 x Shekhar at 75 DAS. Interaction 10^{-6}M GA_3 x Shubhra gave 19.3 and 32.9% higher value at 60 and 75 DAS respectively than 0 M GA_3 x Laxmi 27 which exhibited the poorest activity (Table 14).

4.1.2.3 Leaf chlorophyll content

The pre-sowing seed and foliar treatment of GA_3, followed by 10^{-8}M GA_3, proved best at both stages. Application of 10^{-6}M GA_3 improved leaf chlorophyll content by 14.8 and 12.8% at 60 and 75 DAS respectively over the water treatment.

Table 13. Effect of pre-sowing seed treatment and foliar application of GA_3 on net photosynthetic rate [μmol (CO_2) m^2/s] of linseed cultivars at two stages of growth (Mean of four replicates)

Treatments (T) (M GA_3)		Cultivars (Cv)					Mean
Seed	Spray	Laxmi 27	Parvati	Rashmi	Shekhar	Shubhra	
				60 DAS			
0	0	12.40	13.76	12.49	13.47	13.81	13.19
10^{-8}	10^{-8}	12.91	14.62	13.07	14.35	14.74	13.94
10^{-6}	10^{-6}	13.78	15.59	14.11	15.21	15.80	14.90
Mean		13.03	14.66	13.22	14.34	14.78	
CD at 5%		T = 0.43		Cv = 0.55		T x Cv = 0.96	
				75 DAS			
0	0	13.81	15.18	14.76	15.02	15.60	14.87
10^{-8}	10^{-8}	14.40	16.03	15.39	15.77	16.42	15.60
10^{-6}	10^{-6}	15.38	17.10	16.50	16.88	17.56	16.68
Mean		14.53	16.10	15.55	15.89	16.53	
CD at 5%		T = 0.51		Cv = 0.65		T x Cv = 1.13	

NB : A uniform recommended basal dose of $N_{90}P_{30}K_{30}$ was applied.

Table 14. Effect of pre-sowing seed treatment and foliar application of GA_3 on carbonic anhydrase activity [μmol (CO_2)/kg (f.m.)/s] of linseed cultivars at two stages of growth (Mean of four replicates)

Treatments (T) (M GA_3)		Cultivars (Cv)					Mean
Seed	Spray	Laxmi 27	Parvati	Rashmi	Shekhar	Shubhra	
				60 DAS			
0	0	307.69	328.09	311.47	320.17	331.52	319.79
10^{-8}	10^{-8}	310.85	354.89	335.33	347.00	359.67	341.55
10^{-6}	10^{-6}	333.81	356.01	337.04	349.43	367.09	348.68
Mean		317.45	346.33	327.95	338.87	352.76	
CD at 5%		T = 3.19		Cv = 4.13		T x Cv = 7.15	
				75 DAS			
0	0	356.83	396.40	381.27	397.02	407.31	387.77
10^{-8}	10^{-8}	392.80	446.23	422.90	445.17	461.36	433.69
10^{-6}	10^{-6}	395.94	460.10	426.22	453.71	474.07	442.01
Mean		381.86	434.24	410.13	431.97	447.58	
CD at 5%		T = 5.37		Cv = 6.93		T x Cv = 12.01	

NB : A uniform recommended basal dose of $N_{90}P_{30}K_{30}$ was applied.

Cultivar Shubhra performed best at both the stages. However, it was at par with Shekhar at 60 DAS but was followed by the same (Shekhar) at 75 DAS. Cultivar Shubhra gave 10.0 and 18.2% higher value for leaf chlorophyll content at 60 and 75 DAS respectively than Laxmi 27 which gave the lowest value.

Interaction 10^{-6}M GA_3 x Shubhra, equalled by 10^{-6}M GA_3 x Shekhar, proved best at each stage. Its (10^{-6}M GA_3 x Shubhra) effect was also at par with that of 10^{-6}M GA_3 x Parvati at 60 DAS. Interaction 10^{-6}M GA_3 x Shubhra gave 26.3 and 33.1% higher value at 60 and 75 DAS respectively than 0 M GA_3 x Laxmi 27 which gave the lowest value (Table 15).

4.1.2.4 Leaf N content

The effect of pre-sowing seed and foliar treatment on this parameter was not significant at both stages.

At 75 DAS, cultivar Shubhra equalled by Shekhar and Parvati proved best. Shubhra gave 20.9% higher N content at this stage than Laxmi 27 which gave the lowest value. However, cultivar differences were not significant at 60 DAS.

Interaction 10^{-6} M GA_3 x Shubhra gave the maximum value at 75 DAS, with its effect being at par with that of 10^{-6}M GA_3 x Shekhar, 10^{-8}M GA_3 x Parvati, 10^{-8}M GA_3 x Shubhra, 10^{-6}M GA_3 x Parvati, 10^{-8}M GA_3 x Shekhar, 10^{-8}M GA_3 x Rashmi, 0 M GA_3 x Shubhra, 10^{-6}M GA_3 x Laxmi 27 and 0 M GA_3 x Shekhar. Interaction 10^{-6}M GA_3 x Shubhra gave 49.3% higher value at this stage than 10^{-6}M GA_3 x Rashmi which gave the lowest value. However, interaction effect did not vary at 60 DAS (Table 16).

4.1.2.5 Leaf P content

The effect of pre-sowing seed and foliar treatment of GA_3 and their interaction with cultivars on this parameter as also cultivar differences were not significant at both stages (Table 17).

4.1.2.6 Leaf K content

The effect of GA_3 treatment on this parameter was not significant at both stages.

Cultivar Shekhar, equalled by Parvati, Shubhra and Rashmi, gave maximum value at 75 DAS. Shekhar gave 6.6% higher value at this stage than

Table 15. Effect of pre-sowing seed treatment and foliar application of GA_3 on leaf chlorophyll content (mg/g) of linseed cultivars at two stages of growth (Mean of four replicates)

Treatments (T) (M GA_3)		Cultivars (Cv)					Mean
Seed	Spray	Laxmi 27	Parvati	Rashmi	Shekhar	Shubhra	
				60 DAS			
0	0	1.259	1.329	1.276	1.341	1.351	1.311
10^{-8}	10^{-8}	1.324	1.401	1.316	1.450	1.482	1.395
10^{-6}	10^{-6}	1.437	1.525	1.400	1.572	1.590	1.505
Mean		1.340	1.418	1.331	1.454	1.474	
CD at 5%		T = 0.034		Cv = 0.044		T x Cv = 0.076	
				75 DAS			
0	0	1.348	1.450	1.362	1.481	1.564	1.441
10^{-8}	10^{-8}	1.411	1.553	1.402	1.592	1.676	1.527
10^{-6}	10^{-6}	1.502	1.643	1.471	1.716	1.794	1.625
Mean		1.420	1.549	1.412	1.596	1.678	
CD at 5%		T = 0.051		Cv = 0.065		T x Cv = 0.113	

NB : A uniform recommended basal dose of $N_{90}P_{30}K_{30}$ was applied.

Table 16. Effect of pre-sowing seed treatment and foliar application of GA_3 on leaf N content (%) of linseed cultivars at two stages of growth (Mean of four replicates)

Treatments (T) ($M\ GA_3$)		Cultivars (Cv)					Mean
Seed	Spray	Laxmi 27	Parvati	Rashmi	Shekhar	Shubhra	
				60 DAS			
0	0	1.61	1.81	1.63	1.70	1.82	1.71
10^{-8}	10^{-8}	1.71	1.98	1.76	1.84	2.05	1.87
10^{-6}	10^{-6}	1.78	2.10	1.81	1.93	2.14	1.95
Mean		1.70	1.96	1.73	1.82	2.00	
CD at 5%		T = NS		Cv = NS		T x Cv = NS	
				75 DAS			
0	0	2.21	2.48	2.36	2.51	2.59	2.43
10^{-8}	10^{-8}	2.25	2.78	2.62	2.63	2.77	2.61
10^{-6}	10^{-6}	2.57	2.67	2.11	2.90	3.15	2.68
Mean		2.34	2.64	2.36	2.68	2.83	
CD at 5%		T = NS		Cv = 0.37		T x Cv = 0.64	

NB : A uniform recommended basal dose of $N_{90}P_{30}K_{30}$ was applied.

NS= Non-significant

Table 17. Effect of pre-sowing seed treatment and foliar application of GA_3 on leaf P content (%) of linseed cultivars at two stages of growth (Mean of four replicates)

Treatments (T) (M GA_3)		Cultivars (Cv)					Mean
Seed	Spray	Laxmi 27	Parvati	Rashmi	Shekhar	Shubhra	
				60 DAS			
0	0	0.218	0.221	0.216	0.226	0.219	0.220
10^{-8}	10^{-8}	0.233	0.237	0.229	0.247	0.234	0.236
10^{-6}	10^{-6}	0.240	0.246	0.235	0.257	0.247	0.245
Mean		0.230	0.235	0.227	0.243	0.233	
CD at 5%		T = NS		Cv = NS		T x Cv = NS	
				75 DAS			
0	0	0.235	0.241	0.238	0.251	0.247	0.242
10^{-8}	10^{-8}	0.239	0.255	0.250	0.269	0.262	0.255
10^{-6}	10^{-6}	0.243	0.265	0.255	0.276	0.271	0.262
Mean		0.239	0.254	0.248	0.265	0.260	
CD at 5%		T = NS		Cv = NS		T x Cv = NS	

NB : A uniform recommended basal dose of $N_{90}P_{30}K_{30}$ was applied.

NS= Non-significant

Laxmi 27 which gave the lowest value. However, cultivars did not vary at 60 DAS.

All interactions proved equally effective at both stages (Table 18).

4.1.3 Yield and quality characteristics

The effect of pre-sowing seed and foliar treatment of GA_3 and their interactions with cultivars, as also cultivar differences were significant on all yield characteristics, except seeds per capsule, 1000-seed weight, harvest index and oil content and iodine value. However, cultivars did not vary for lodging (Tables 19-25).

4.1.3.1 Capsules per plant

Increasing levels of pre-sowing seed and foliar treatment of GA_3 increased capsules per plant linearly. Application of 10^{-6}M GA_3 gave 29.5% higher value than the water treatment.

Cultivar Shubhra, followed by Shekhar, proved best and gave 27.6% higher number of capsules per plant than Laxmi 27 which gave the least value.

Interaction 10^{-6}M GA x Shubhra, followed by 10^{-6}M GA_3 x Shekhar (or Parvati) and 10^{-8}M GA_3 x Shubhra gave the maximum value. Interaction 10^{-6}M GA_3 x Shubhra gave 67.5% higher value than 0 M GA_3 x Laxmi 27 which gave the least number (Table 19).

4.1.3.2 Seeds per capsule

The effect of GA_3 treatments and their interactions with cultivars on this parameter as also cultivar differences were not significant (Table 19).

4.1.3.3 1000-seed weight

The effect of treatments, cultivar differences and their interactions on the seed weight were not significant (Table 20).

4.1.3.4 Seed yield per plant

The pre-sowing seed and foliar treatment at 10^{-6}M GA_3 followed by 10^{-8}M GA_3, gave the maximum seed yield. Treatment 10^{-6}M GA_3 gave 24.7% higher seed yield than 0 M GA_3.

Table 18. Effect of pre-sowing seed treatment and foliar application of GA_3 on leaf K content (%) of linseed cultivars at two stages of growth (Mean of four replicates)

Treatments (T) (M GA_3)		Cultivars (Cv)					Mean
Seed	Spray	Laxmi 27	Parvati	Rashmi	Shekhar	Shubhra	
				60 DAS			
0	0	2.34	2.49	2.38	2.41	2.52	2.43
10^{-8}	10^{-8}	2.46	2.52	2.43	2.48	2.61	2.50
10^{-6}	10^{-6}	2.49	2.62	2.51	2.53	2.69	2.57
Mean		2.43	2.54	2.44	2.47	2.61	
CD at 5%		T = NS		Cv = NS		T x Cv = NS	
				75 DAS			
0	0	2.52	2.63	2.55	2.76	2.59	2.61
10^{-8}	10^{-8}	2.59	2.68	2.61	2.74	2.64	2.65
10^{-6}	10^{-6}	2.67	2.72	2.68	2.79	2.70	2.71
Mean		2.59	2.68	2.61	2.76	2.64	
CD at 5%		T = NS		Cv = 0.06		T x Cv = NS	

NB : A uniform recommended basal dose of $N_{90}P_{30}K_{30}$ was applied.

NS= Non-significant

Table 19. Effect of pre-sowing seed treatment and foliar application of GA_3 on capsules per plant and seeds per capsule of linseed cultivars at harvest (Mean of four replicates)

Treatments (T) (M GA_3)		Cultivars (Cv)					Mean
Seed	Spray	Laxmi 27	Parvati	Rashmi	Shekhar	Shubhra	
				Capsules per plant			
0	0	51.33	55.67	48.00	58.33	62.67	55.20
10^{-8}	10^{-8}	55.67	62.00	52.37	66.67	70.33	61.41
10^{-6}	10^{-6}	64.67	70.00	61.00	75.67	86.00	71.47
Mean		57.22	62.56	53.79	66.89	73.00	
CD at 5%		T = 2.75		Cv = 3.55		T x Cv = 6.15	
				Seeds per capsule			
0	0	8.00	9.11	8.28	8.57	8.93	8.58
10^{-8}	10^{-8}	7.98	8.76	8.39	8.46	9.15	8.55
10^{-6}	10^{-6}	8.15	9.28	8.37	8.98	9.30	8.82
Mean		8.04	9.05	8.35	8.67	9.13	
CD at 5%		T = NS		Cv = NS		T x Cv = NS	

NB : A uniform recommended basal dose of $N_{90}P_{30}K_{30}$ was applied.

NS= Non-significant

Table 20. Effect of pre-sowing seed treatment and foliar application of GA_3 on 1000-seed weight and seed yield per plant of linseed cultivars at harvest (Mean of four replicates)

Treatments (T) ($M\ GA_3$)		Cultivars (Cv)					Mean
Seed	Spray	Laxmi 27	Parvati	Rashmi	Shekhar	Shubhra	
		1000-seed weight (g)					
0	0	7.56	7.91	7.69	7.80	8.18	7.83
10^{-8}	10^{-8}	7.62	7.85	7.66	7.73	8.22	7.82
10^{-6}	10^{-6}	7.86	8.30	8.02	8.12	8.54	8.17
Mean		7.68	8.02	7.79	7.88	8.31	
CD at 5%		T = NS		Cv = NS		T x Cv = NS	
		Seed yield per plant (g)					
0	0	2.21	2.38	2.31	2.32	2.49	2.31
10^{-8}	10^{-8}	2.51	2.77	2.40	2.81	2.89	2.68
10^{-6}	10^{-6}	2.68	2.99	2.58	2.94	3.20	2.88
Mean		2.47	2.71	2.37	2.69	2.86	
CD at 5%		T = 0.08		Cv = 0.11		T x Cv = 0.19	

NB : A uniform recommended basal dose of $N_{90}P_{30}K_{30}$ was applied.

NS= Non-significant

Among cultivars, Shubhra performed best. It was followed by Parvati and Shekhar. Shubhra gave 15.8% higher seed yield than Laxmi 27 which gave the lowest value.

Of interactions, 10^{-6}M GA_3 x Shubhra gave the maximum seed yield. Its effect was followed by that of 10^{-6}M GA_3 x Parvati (or Shekhar) and 10^{-8}M GA_3 x Shubhra (or Shekhar). Interaction 10^{-6}M GA_3 x Shubhra gave 44.8% higher value than 0 M GA_3 x Laxmi 27 which gave the lowest value (Table 20).

4.1.3.5 Biological yield per plant

Increasing levels of pre-sowing seed and foliar treatment of GA_3 increased biological yield linearly. Application of 10^{-6}M GA_3 gave 20.5% higher value than 0 M GA_3.

Among cultivars, Shubhra gave the maximum value. It was followed by Parvati and Shekhar. Shubhra gave 23.6% higher biological yield than Laxmi 27 which exhibited the least value.

Of interactions, 10^{-6}M GA_3 x Shubhra gave the maximum value, however, its effect was equalled by that of 10^{-6}M GA_3 x Parvati and 10^{-8}M GA_3 x Shubhra. Interaction 10^{-6}M GA_3 x Shubhra gave 50.6% higher value than 0 M GA_3 x Laxmi 27 which gave the lowest value (Table 21).

4.1.3.6 Harvest index

The effect of GA_3 treatments and their interactions with cultivars on this parameter as also cultivar differences were not significant (Table 21).

4.1.3.7 Oil content

The effect of GA_3 treatments and their interactions with cultivars on oil content as also cultivar differences were not significant (Table 22).

4.1.3.8 Oil yield per plant

Treatment 10^{-6}M GA_3, followed by 10^{-8}M GA_3, gave the maximum oil yield per plant. Application of 10^{-6}M GA_3 gave 27.1% higher oil yield than the water treatment.

Cultivar Shubhra performed the best. It was followed by Parvati and Shekhar. Shubhra gave 25.1% higher value than Rashmi which gave the lowest value.

Table 21. Effect of pre-sowing seed treatment and foliar application of GA_3 on biological yield per plant and harvest index of linseed cultivars at harvest (Mean of four replicates)

Treatments (T) (M GA_3)		Cultivars (Cv)					Mean
Seed	Spray	Laxmi 27	Parvati	Rashmi	Shekhar	Shubhra	
		Biological yield per plant (g)					
0	0	8.15	9.39	8.07	8.85	9.90	8.87
10^{-8}	10^{-8}	9.26	10.94	9.01	10.57	11.32	10.22
10^{-6}	10^{-6}	9.68	11.36	9.28	10.84	12.27	10.69
Mean		9.03	10.56	8.79	10.09	11.16	
CD at 5%		T = 0.43		Cv = 0.55		T x Cv = 0.96	
		Harvest index (%)					
0	0	27.12	25.35	26.41	26.21	25.14	26.05
10^{-8}	10^{-8}	27.11	25.32	26.64	26.58	25.54	26.24
10^{-6}	10^{-6}	27.69	26.32	27.80	27.12	26.07	27.00
Mean		27.31	25.66	26.59	26.64	25.58	
CD at 5%		T = NS		Cv = NS		T x Cv = NS	

NB : A uniform recommended basal dose of $N_{90}P_{30}K_{30}$ was applied.

NS= Non-significant

Table 22. Effect of pre-sowing seed treatment and foliar application of GA_3 on oil content and oil yield per plant of linseed cultivars at harvest (Mean of four replicates)

Treatments (T) (M GA_3)		Cultivars (Cv)					Mean
Seed	Spray	Laxmi 27	Parvati	Rashmi	Shekhar	Shubhra	
				Oil content (%)			
0	0	37.86	38.47	37.10	38.35	38.31	38.06
10^{-8}	10^{-8}	37.79	38.69	37.27	38.79	38.52	38.21
10^{-6}	10^{-6}	38.42	39.06	37.68	39.33	39.15	38.73
Mean		38.02	38.74	37.35	38.89	38.66	
CD at 5%		T = NS		Cv = NS		T x Cv = NS	
				Oil yield per plant (g)			
0	0	0.837	0.916	0.790	0.894	0.954	0.878
10^{-8}	10^{-8}	0.949	1.072	0.894	1.090	1.113	1.024
10^{-6}	10^{-6}	1.030	1.168	0.972	1.156	1.253	1.116
Mean		0.939	1.052	0.885	1.047	1.107	
CD at 5%		T = 0.024		Cv = 0.031		T x Cv = 0.054	

NB : A uniform recommended basal dose of $N_{90}P_{30}K_{30}$ was applied.

NS= Non-significant

Of interactions, 10^{-6}M GA_3 x Shubhra surpassed other interactions. Its effect was followed by that of 10^{-6}M GA_3 x Parvati (or Shekhar). Interaction 10^{-6}M GA_3 x Shubhra improved oil yield by 49.7% over 0 M GA_3 x Laxmi 27 which gave the lowest value (Table 22).

4.1.3.9 Iodine value

Effect of treatments and their interactions with cultivars on iodine value as also cultivar differences were found not-significant (Table 23).

4.1.3.10 Fibre yield per plant

Increasing levels of GA_3 increased fibre yield per plant linearly. Application of 10^{-6}M GA_3 increased fibre yield per plant by 55.9% than the water treatment.

Cultivars Shubhra and Parvati, being at par, gave the maximum value. Shubhra gave 35.5% higher fibre yield than Laxmi 27 which gave the lowest value.

Interaction 10^{-6}M GA_3 x Shubhra gave the maximum value. However, its effect was at par with that of 10^{-6}M GA_3 x Parvati. Interaction 10^{-6}M GA_3 x Shubhra gave 105.8% higher value than 0 M GA_3 x Laxmi 27 which gave the lowest value (Table 24).

4.1.3.11 Lodging

Increasing levels of pre-sowing seed and foliar treatment of GA_3 increased lodging linearly. Application of 10^{-6}M GA_3 enhanced lodging by 43.7% over the water treatment.

Cultivars did not vary in respect of this parameter.

Of interactions, 10^{-6}M GA_3 x Shubhra gave the maximum value, however, its effect was equalled by that of 10^{-6}M GA_3 x Laxmi 27, 10^{-6}M GA_3 x Shekhar, 10^{-6}M GA_3 x Rashmi and 10^{-6}M GA_3 x Parvati. Interaction 10^{-6}M GA_3 x Shubhra increased lodging by 67.4% over 0 M GA_3 x Laxmi 27 which proved least effective (Table 25)

4.2 Experiment 2

The aim of this factorial randomized experiment was to maximize the performance of the three best performing linseed cultivars (Parvati, Shekhar and

Table 23. Effect of pre-sowing seed treatment and foliar application of GA_3 on iodine value of linseed cultivars at harvest (Mean of four replicates)

Treatments (T) ($M\ GA_3$)		Cultivars (Cv)					Mean
Seed	Spray	Laxmi 27	Parvati	Rashmi	Shekhar	Shubhra	
				Iodine value			
0	0	201.14	188.27	198.20	191.37	182.59	192.31
10^{-8}	10^{-8}	198.00	186.40	195.57	190.33	179.32	189.92
10^{-6}	10^{-6}	198.76	183.28	191.61	186.28	179.11	187.81
Mean		199.30	185.98	195.13	189.33	180.34	
CD at 5%		T = NS		Cv = NS		T x Cv = NS	

NB : A uniform recommended basal dose of $N_{90}P_{30}K_{30}$ was applied.

NS= Non-significant

Table 24. Effect of pre-sowing seed treatment and foliar application of GA_3 on fibre yield per plant of linseed cultivars at harvest (Mean of four replicates)

Treatments (T) (M GA_3)		Cultivars (Cv)					Mean
Seed	Spray	Laxmi 27	Parvati	Rashmi	Shekhar	Shubhra	
		Fibre yield per plant (g)					
0	0	0.791	0.975	0.820	0.868	0.969	0.885
10^{-8}	10^{-8}	1.014	1.256	1.057	1.132	1.369	1.166
10^{-6}	10^{-6}	1.123	1.567	1.262	1.321	1.628	1.380
Mean		0.976	1.266	1.046	1.107	1.322	
CD at 5%		T = 0.072		Cv = 0.094		T x Cv = 0.162	

NB : A uniform recommended basal dose of $N_{90}P_{30}K_{30}$ was applied.

Table 25. Effect of pre-sowing seed treatment and foliar application of GA_3 on lodging of linseed cultivars at harvest (Mean of four replicates)

Treatments (T) (M GA_3)		Cultivars (Cv)					Mean
Seed	Spray	Laxmi 27	Parvati	Rashmi	Shekhar	Shubhra	
				Lodging (%)			
0	0	18.7	20.0	21.7	19.3	20.0	19.9
10^{-8}	10^{-8}	23.3	20.7	22.3	23.0	23.7	22.6
10^{-6}	10^{-6}	28.7	27.3	27.7	28.0	31.3	28.6
Mean		23.6	22.7	23.9	23.4	25.0	
CD at 5%		T = 2.15		Cv = NS		T x Cv = 4.81	

NB : A uniform recommended basal dose of $N_{90}P_{30}K_{30}$ was applied.

NS= Non-significant

Shubhra, selected in Experiment 1) by the application of basal combinations of N and P (in the presence of a uniform dose of 30 kg K/ha and the best pre-sowing seed and foliar treatment of GA_3, i.e. 10^{-6}M, emanated from the data of Experiment 1). The parameters studied at 60 and 75 DAS were kept the same as in Experiment 1. The results (Tables 26-43) are summarized below.

4.2.1 Growth characteristics

The effect of nutrient combinations and their interactions with cultivars on all growth characteristics as also cultivar differences were significant at both stages (Tables 26-30).

4.2.1.1 Height per plant

Treatment $N_{60}P_{20}$ proved best at both stages. However, its effect was equalled at 60 DAS and followed at 75 DAS by that of $N_{90}P_{30}$. Treatment $N_{60}P_{20}$ gave 18.7 and 28.7% higher value at 60 and 75 DAS respectively than N_0P_0.

Cultivar Shubhra, followed by Shekhar and Parvati, gave the maximum value at both stages. Shubhra increased this parameter by 7.6 and 8.9% at 60 and 75 DAS respectively over Parvati which gave the lowest value.

Interaction $N_{60}P_{20}$ x Shubhra gave the maximum value at both stages. However, its effect was equalled by that of $N_{90}P_{30}$ x Shubhra and $N_{60}P_{20}$ x Parvati at both stages (also by that of $N_{60}P_{20}$ x Shekhar at 75 DAS). Interaction $N_{60}P_{20}$ x Shubhra gave 31.6 and 38.6% higher value at 60 and 75 DAS respectively than N_0P_0 x Parvati which gave the lowest value (Table 26).

4.2.1.2 Leaf area per plant

Treatment $N_{60}P_{20}$ proved best at both stages, with $N_{90}P_{30}$ giving equal value. Treatment $N_{60}P_{20}$ gave 27.8 and 22.5% higher value at 60 and 75 DAS respectively than N_0P_0 which gave the lowest value.

Cultivar Shubhra, followed by Shekhar, gave maximum value at both growth stages. Shubhra gave 8.7 and 10.9% higher value at 60 and 75 DAS respectively than Parvati which gave the lowest value.

Interaction $N_{60}P_{20}$ x Shubhra proved best at both stages, with its effect being at par with that of $N_{90}P_{30}$ x Shubhra. Interaction $N_{60}P_{20}$ x Shubhra gave 38.5 and 36.1% higher value at 60 and 75 DAS respectively than N_0P_0 x Parvati which gave the lowest value (Table 27).

Table 26. Effect of basal N and P on height per plant (cm) of linseed cultivars at two stages of growth (Mean of four replicates)

Treatments (T) (kg/ha)	Cultivars (Cv)			Mean
	Parvati	Shekhar	Shubhra	
		60 DAS		
N_0P_0	56.7	56.4	58.2	57.1
$N_{30}P_{10}$	59.3	58.7	62.4	60.1
$N_{60}P_{20}$	69.4	67.9	74.6	70.6
$N_{90}P_{30}$	66.3	65.2	71.8	67.8
Mean	62.9	62.1	66.8	
CD at 5%	T= 3.71	Cv = 3.21	T x Cv = 6.42	
		75 DAS		
N_0P_0	62.4	64.5	66.7	64.5
$N_{30}P_{10}$	65.3	68.2	71.6	68.4
$N_{60}P_{20}$	79.7	82.8	86.5	83.0
$N_{90}P_{30}$	75.2	76.6	83.2	78.3
Mean	70.7	73.0	77.0	
CD at 5%	T = 2.60	Cv = 2.26	T x Cv = 4.51	

NB: A uniform pre-sowing seed and spray treatment of 10^{-6}M GA_3 as well as a basal dose of K_{30} was applied.

Table 27. Effect of basal N and P on leaf area per plant (cm^2) of linseed cultivars at two stages of growth (Mean of four replicates)

Treatments (T) (kg/ha)	Cultivars (Cv)			Mean
	Parvati	Shekhar	Shubhra	
		60 DAS		
N_0P_0	168.19	171.38	176.52	172.03
$N_{30}P_{10}$	178.57	182.60	188.31	183.16
$N_{60}P_{20}$	206.41	220.00	232.89	219.77
$N_{90}P_{30}$	207.16	216.81	228.47	217.48
Mean	190.08	197.70	206.55	
CD at 5%	T= 3.30	Cv = 2.86	T x Cv = 5.72	
		75 DAS		
N_0P_0	311.00	321.61	335.49	322.70
$N_{30}P_{10}$	328.51	340.18	351.24	339.98
$N_{60}P_{20}$	371.41	391.52	423.36	395.43
$N_{90}P_{30}$	369.20	393.10	421.00	399.11
Mean	345.03	365.11	382.77	
CD at 5%	T = 4.69	Cv = 4.07	T x Cv = 8.13	

NB: A uniform pre-sowing seed and spray treatment of $10^{-6}M\ GA_3$ as well as a basal dose of K_{30} was applied.

4.2.1.3 Leaf area index

Treatment $N_{60}P_{20}$ gave the maximum value at each stage. However, its effect was at par with that of $N_{90}P_{30}$ at both stages. Application of $N_{60}P_{20}$ resulted in 27.7 and 22.5% higher value at 60 and 75 DAS respectively than N_0P_0.

Among cultivars, Shubhra proved best at both stages, with Shekhar following it. Shubhra gave 8.5 and 10.8% higher value at 60 and 75 DAS respectively than Parvati which gave the lowest value.

Among interactions, $N_{60}P_{20}$ x Shubhra gave the maximum value. However, its effect was at par with that of $N_{90}P_{30}$ x Shubhra and $N_{60}P_{20}$ x Shekhar at both stages (also that of $N_{90}P_{30}$ x Shekhar at 75 DAS). Interaction $N_{60}P_{20}$ x Shubhra gave 38.6 and 36.2% higher value at 60 and 75 DAS respectively than N_0P_0 x Parvati which gave the lowest value (Table 28).

4.2.1.4 Fresh weight per plant

Treatment $N_{60}P_{20}$ proved best at both stages, with $N_{90}P_{30}$ giving equal value. Treatment $N_{60}P_{20}$ gave 74.6 and 60.8% higher value at 60 and 75 DAS respectively than N_0P_0.

Cultivar Shubhra gave the maximum value at both stages. However, it was equalled at 60 DAS and followed at 75 DAS by Shekhar. Cultivar Shubhra gave 23.9 and 22.3% higher value at 60 and 75 DAS respectively than Parvati which gave the minimum value.

Interactions $N_{60}P_{20}$ x Shubhra and $N_{90}P_{30}$ x Shubhra, being at par, gave the maximum value at both stages. However, their effect was at par with that of $N_{60}P_{20}$ x Shekhar and $N_{90}P_{30}$ x Shekhar at 60 DAS. Interaction $N_{60}P_{20}$ x Shubhra gave 111.6 and 92.1% higher value at 60 and 75 DAS respectively over N_0P_0 x Parvati which gave the least value (Table 29).

4.2.1.5 Dry weight per plant

Treatment $N_{60}P_{20}$ proved best at both stages, with $N_{90}P_{30}$ giving equal value. Treatment $N_{60}P_{20}$ gave 60.8 and 51.5% more dry matter at 60 and 75 DAS respectively than N_0P_0.

Table 28. Effect of basal N and P on leaf area index of linseed cultivars at two stages of growth (Mean of four replicates)

Treatments (T) (kg/ha)	Cultivars (Cv)			Mean
	Parvati	Shekhar	Shubhra	
		60 DAS		
N_0P_0	3.42	3.49	3.59	3.50
$N_{30}P_{10}$	3.64	3.72	3.83	3.73
$N_{60}P_{20}$	4.20	4.48	4.74	4.47
$N_{90}P_{30}$	4.42	4.42	4.65	4.43
Mean	3.87	4.03	4.20	
CD at 5%	T= 0.18	Cv = 0.14	T x Cv = 0.31	
		75 DAS		
N_0P_0	6.33	6.55	6.83	6.57
$N_{30}P_{10}$	6.69	6.93	7.15	6.92
$N_{60}P_{20}$	7.56	7.97	8.62	8.05
$N_{90}P_{30}$	7.52	8.00	8.57	8.03
Mean	7.03	7.36	7.79	
CD at 5%	T = 0.40	Cv = 0.35	T x Cv = 0.70	

NB: A uniform pre-sowing seed and spray treatment of 10^{-6}M GA_3 as well as a basal dose of K_{30} was applied.

Table 29. Effect of basal N and P on fresh weight per plant (g) of linseed cultivars at two stages of growth (Mean of four replicates)

Treatments (T) (kg/ha)	Cultivars (Cv)			Mean
	Parvati	Shekhar	Shubhra	
		60 DAS		
N_0P_0	13.10	14.38	16.17	14.55
$N_{30}P_{10}$	15.41	16.44	19.05	16.97
$N_{60}P_{20}$	22.73	25.75	27.72	25.40
$N_{90}P_{30}$	20.14	25.17	26.00	23.77
Mean	17.85	20.44	22.11	
CD at 5%	T= 2.61	Cv = 2.26	T x Cv = 4.52	
		75 DAS		
N_0P_0	21.47	23.61	25.39	23.49
$N_{30}P_{10}$	24.80	26.68	29.10	26.86
$N_{60}P_{20}$	34.16	37.90	41.24	37.77
$N_{90}P_{30}$	34.41	37.62	43.55	38.19
Mean	28.46	31.45	34.82	
CD at 5%	T = 2.08	Cv = 1.81	T x Cv = 3.61	

NB: A uniform pre-sowing seed and spray treatment of 10^{-6}M GA_3 as well as a basal dose of K_{30} was applied.

Among cultivars, Shubhra performed best. It was followed by Shekhar at each growth stage. Cultivar Shubhra gave 28.1 and 17.1% higher value at 60 and 75 DAS *respectively than Parvati which gave the lowest value.*

Interactions $N_{60}P_{20}$ x Shubhra and $N_{90}P_{30}$ x Shubhra, being at par, gave the maximum value at each stage. Interaction $N_{60}P_{20}$ x Shubhra gave 106.2 and 73.1% higher value at 60 and 75 DAS respectively than N_0P_0 x Parvati which gave the lowest value (Table 30).

4.2.2 Physiological and biochemical parameters

The effect of treatments on all physiological and biochemical parameters and cultivar differences, alone as well as in combination, were significant at both stages, except leaf K content (Tables 31-36).

4.2.2.1 Net photosynthetic rate

Treatment $N_{60}P_{20}$, being at par with $N_{90}P_{30}$, proved superior at each sampling stage. Treatment $N_{60}P_{20}$ gave 10.5 and 10.8% higher value at 60 and 75 DAS respectively than N_0P_0.

Cultivar Shubhra, followed by Shekhar, performed best at both the stages. Shubhra gave 14.6 and 10.7% higher value at 60 and 75 DAS respectively than Parvati which gave the lowest value.

Interactions $N_{60}P_{20}$ x Shubhra and $N_{90}P_{30}$ x Shubhra, being at par, gave the maximum value at both stages. Interaction $N_{60}P_{20}$ x Shubhra gave 26.7 and 23.6% higher value at 60 and 75 DAS respectively than N_0P_0 x Parvati which gave the lowest value (Table 31).

4.2.2.2 Carbonic anhydrase activity

Treatment $N_{60}P_{20}$, being at par with $N_{90}P_{30}$, proved best at both stages. Treatments $N_{60}P_{20}$ increased CA activity by 34.0 and 27.5% at 60 and 75 DAS respectively over N_0P_0.

Cultivar Shubhra, followed by Shekhar, performed best at each stage. Cultivar Shubhra gave 7.2 and 7.3% higher value at 60 and 75 DAS respectively than Parvati which gave the lowest value.

Among interactions, $N_{60}P_{20}$ x Shubhra proved best at both stages. However, its effect was equalled at 60 DAS and followed at 75 DAS by that of

Table 30. Effect of basal N and P on dry weight per plant (g) of linseed cultivars at two stages of growth (Mean of four replicates)

Treatments (T) (kg/ha)	Cultivars (Cv)			Mean
	Parvati	Shekhar	Shubhra	
		60 DAS		
N_0P_0	2.76	2.83	3.68	3.09
$N_{30}P_{10}$	3.21	3.47	3.76	3.48
$N_{60}P_{20}$	4.38	4.84	5.69	4.97
$N_{90}P_{30}$	4.45	4.81	5.83	5.03
Mean	3.70	3.99	4.74	
CD at 5%	T= 0.32	Cv = 0.28	T x Cv = 0.56	
		75 DAS		
N_0P_0	4.69	4.81	5.11	4.87
$N_{30}P_{10}$	5.06	5.40	5.83	5.43
$N_{60}P_{20}$	6.69	7.33	8.12	7.38
$N_{90}P_{30}$	6.72	7.29	8.07	7.46
Mean	5.79	6.21	6.78	
CD at 5%	T = 0.18	Cv = 0.16	T x Cv = 0.32	

NB: A uniform pre-sowing seed and spray treatment of 10^{-6}M GA_3 as well as a basal dose of K_{30} was applied.

Table 31. Effect of basal N and P on net photosynthetic rate [μmol (CO_2) m^2/s] of linseed cultivars at two stages of growth (Mean of four replicates)

Treatments (T) (kg/ha)	Cultivars (Cv)			Mean
	Parvati	Shekhar	Shubhra	
		60 DAS		
N_0P_0	15.29	16.10	16.72	16.04
$N_{30}P_{10}$	15.41	16.55	17.04	16.33
$N_{60}P_{20}$	16.10	17.94	19.12	17.72
$N_{90}P_{30}$	16.22	18.06	19.37	17.88
Mean	15.76	17.16	18.06	
CD at 5%	T= 0.59	Cv = 0.51	T x Cv = 1.02	
		75 DAS		
N_0P_0	17.18	18.53	18.86	18.19
$N_{30}P_{10}$	17.32	18.89	19.11	18.44
$N_{60}P_{20}$	19.07	20.16	21.23	20.15
$N_{90}P_{30}$	19.01	20.10	21.16	20.09
Mean	18.15	19.42	20.09	
CD at 5%	T = 0.50	Cv = 0.43	T x Cv = 0.86	

NB: A uniform pre-sowing seed and spray treatment of 10^{-6}M GA_3 as well as a basal dose of K_{30} was applied.

$N_{90}P_{30}$ x *Shubhra*. *Interaction* $N_{60}P_{20}$ x *Shubhra* gave 41.3 and 36.5% higher value at 60 and 75 DAS respectively than N_0P_0 x Parvati which gave the lowest value (Table 32).

4.2.2.3 Leaf chlorophyll content

Among nutrient levels, $N_{60}P_{20}$ proved best at both stages. However, its effect was at par with that of $N_{90}P_{30}$ at each stage. Treatment $N_{60}P_{20}$ increased leaf chlorophyll content by 19.7 and 14.8% at 60 and 75 DAS respectively over N_0P_0.

Of cultivars, Shubhra proved best at each stage. However, it was followed by Parvati and Shekhar at both stages. Shubhra showed 2.5 and 2.4% higher values for chlorophyll content at 60 and 75 DAS respectively than Parvati which gave the lowest value.

Interaction $N_{60}P_{20}$ x Shubhra at 60 DAS and $N_{90}P_{30}$ x Shubhra at 75 DAS gave the maximum value. However, their effect was at par with that of $N_{60}P_{20}$ x Shekhar at both stages and also by that of $N_{90}P_{30}$ x Shekhar at 75 DAS. Interaction $N_{60}P_{20}$ x Shubhra enhanced leaf chlorophyll content by 22.1 and 17.2% at 60 and 75 DAS respectively over N_0P_0 x Parvati which gave the least value (Table 33).

4.2.2.4 Leaf N content

Treatment $N_{60}P_{20}$ gave the maximum value at both stages, with $N_{90}P_{30}$ giving equal value. Treatment $N_{60}P_{20}$ increased N content by 47.6 and 39.2% at 60 and 75 DAS respectively over N_0P_0.

Cultivar Shubhra, followed by Shekhar, performed the best at both stages. Cultivar Shubhra gave 33.0 and 27.9% higher value at 60 and 75 DAS respectively than Parvati that gave the lowest value.

Interactions $N_{60}P_{20}$ x Shubhra and $N_{90}P_{30}$ x Shubhra, being at par, gave the maximum value at both stages. Interaction $N_{60}P_{20}$ x Shubhra gave 91.5 and 72.0% more N content at 60 and 75 DAS respectively than N_0P_0 x Parvati that gave the lowest value (Table 34).

4.2.2.5 Leaf P content

Treatment $N_{60}P_{20}$, being at par with $N_{90}P_{30}$, proved best at both stages. Treatment $N_{60}P_{20}$ improved P content by 18.9 and 15.8% at 60 and 75 DAS *respectively over* N_0P_0.

Table 32. Effect of basal N and P on carbonic anhydrase activity [µmol (CO_2)/kg (f.m.)/s] of linseed cultivars at two stages of growth (Mean of four replicates)

Treatments (T) (kg/ha)	Cultivars (Cv) Parvati	Shekhar	Shubhra	Mean
		60 DAS		
N_0P_0	359.35	353.28	368.27	360.30
$N_{30}P_{10}$	370.46	362.91	384.54	372.64
$N_{60}P_{20}$	463.43	476.75	507.73	482.64
$N_{90}P_{30}$	467.52	471.16	519.26	485.98
Mean	415.19	416.03	444.95	
CD at 5%	T= 16.21	Cv = 14.04	T x Cv = 28.07	
		75 DAS		
N_0P_0	418.59	439.25	453.97	437.27
$N_{30}P_{10}$	430.06	451.16	469.39	450.20
$N_{60}P_{20}$	542.18	558.52	571.40	557.37
$N_{90}P_{30}$	533.00	541.73	568.91	547.88
Mean	480.96	497.67	515.92	
CD at 5%	T = 14.66	Cv = 12.70	T x Cv = 25.39	

NB: A uniform pre-sowing seed and spray treatment of 10^{-6}M GA_3 as well as a basal dose of K_{30} was applied.

Table 33. Effect of basal N and P on leaf chlorophyll content (mg/g f.m.) of linseed cultivars at two stages of growth (Mean of four replicates)

Treatments (T) (kg/ha)	Cultivars (Cv)			Mean
	Parvati	Shekhar	Shubhra	
		60 DAS		
N_0P_0	1.352	1.349	1.362	1.354
$N_{30}P_{10}$	1.453	1.451	1.476	1.460
$N_{60}P_{20}$	1.593	1.620	1.651	1.621
$N_{90}P_{30}$	1.586	1.614	1.646	1.615
Mean	1.496	1.509	1.534	
CD at 5%	T= 0.018	Cv = 0.016	T x Cv = 0.032	
		75 DAS		
N_0P_0	1.521	1.528	1.556	1.535
$N_{30}P_{10}$	1.602	1.611	1.632	1.615
$N_{60}P_{20}$	1.742	1.760	1.783	1.762
$N_{90}P_{30}$	1.731	1.753	1.785	1.756
Mean	1.649	1.663	1.689	
CD at 5%	T = 0.024	Cv = 0.021	T x Cv = 0.041	

NB: A uniform pre-sowing seed and spray treatment of 10^{-6}M GA_3 as well as a basal dose of K_{30} was applied.

Table 34. Effect of basal N and P on leaf N content (%) of linseed cultivars at two stages of growth (Mean of four replicates)

Treatments (T) (kg/ha)	Cultivars (Cv)			Mean
	Parvati	Shekhar	Shubhra	
		60 DAS		
N_0P_0	1.77	1.86	2.11	1.91
$N_{30}P_{10}$	2.10	2.17	2.51	2.26
$N_{60}P_{20}$	2.43	2.65	3.39	2.82
$N_{90}P_{30}$	2.29	2.57	3.42	2.76
Mean	2.15	2.31	2.86	
CD at 5%	T= 0.15	Cv = 0.13	T x Cv = 0.26	
		75 DAS		
N_0P_0	2.07	2.17	2.58	2.27
$N_{30}P_{10}$	2.37	2.47	3.04	2.63
$N_{60}P_{20}$	2.83	3.04	3.56	3.16
$N_{90}P_{30}$	2.60	3.15	3.44	3.06
Mean	2.47	2.72	3.16	
CD at 5%	T = 0.16	Cv = 0.14	T x Cv = 0.28	

NB: A uniform pre-sowing seed and spray treatment of 10^{-6}M GA_3 as well as a basal dose of K_{30} was applied.

Cultivar Shubhra gave the maximum value at both stages. However, it was equalled at 60 DAS and followed at 75 DAS by Shekhar. Cultivar Shubhra gave 4.6 and 8.2% higher value at 60 and 75 DAS respectively than Parvati which gave the lowest value.

Interaction $N_{90}P_{30}$ x Shubhra at 60 DAS and $N_{60}P_{20}$ x Shubhra at 75 DAS gave the maximum value. However, their effect was at par with that of $N_{90}P_{30}$ x Shekhar, $N_{60}P_{20}$ x Shekhar, $N_{90}P_{30}$ x Parvati, $N_{30}P_{10}$ x Shubhra, $N_{60}P_{20}$ x Parvati at 60 DAS and with that of $N_{60}P_{20}$ x Shekhar at 75 DAS. Interaction $N_{60}P_{20}$ x Shubhra gave 24.2 and 23.5% higher value at 60 and 75 DAS respectively than N_0P_0 x Parvati which gave the lowest value (Table 35).

4.2.2.6 Leaf K content

The effect of treatments and their interaction on this parameter as also cultivar differences were not significant at both stages (Table 36).

4.2.3 Yield and quality characteristics

The effect of nutrients and their interactions with cultivars on all yield characteristics as also cultivar differences were significant, except seeds per capsule, harvest index and oil content. However, treatment effect on lodging, cultivar differences for 1000-seed weight and lodging as also interaction effect on 1000-seed weight and iodine value were not significant (Tables 37-43).

4.2.3.1 Capsules per plant

Treatment $N_{60}P_{20}$, followed by $N_{90}P_{30}$, was found most effective in enhancing capsule number per plant. Treatment $N_{60}P_{20}$ increased capsule number per plant by 118.1% over N_0P_0.

Cultivar Shubhra performed best, with Parvati (and Shekhar) occupying the second position. Shubhra gave 14.1% more capsules than Parvati which gave the minimum value.

Interaction $N_{60}P_{20}$ x Shubhra, followed by $N_{90}P_{30}$ x Shubhra, gave the maximum value for this parameter. Interaction $N_{60}P_{20}$ x Shubhra gave 108.2% higher value than N_0P_0 x Shekhar that gave the lowest value (Table 37).

4.2.3.2 Seeds per capsule

The effect of treatments and their interactions with cultivars on this parameter as also cultivar differences were not significant (Table 37).

Table 35. Effect of basal N and P on leaf P content (%) of linseed cultivars at two stages of growth (Mean of four replicates)

Treatments (T) (kg/ha)	Cultivars (Cv) Parvati	Shekhar	Shubhra	Mean
		60 DAS		
N_0P_0	0.215	0.217	0.220	0.217
$N_{30}P_{10}$	0.243	0.240	0.253	0.245
$N_{60}P_{20}$	0.250	0.258	0.267	0.258
$N_{90}P_{30}$	0.254	0.263	0.269	0.262
Mean	0.241	0.245	0.252	
CD at 5%	T= 0.011	Cv = 0.009	T x Cv = 0.019	
		75 DAS		
N_0P_0	0.251	0.248	0.259	0.253
$N_{30}P_{10}$	0.263	0.270	0.285	0.273
$N_{60}P_{20}$	0.281	0.287	0.310	0.293
$N_{90}P_{30}$	0.276	0.281	0.306	0.288
Mean	0.268	0.272	0.290	
CD at 5%	T = 0.014	Cv = 0.0.12	T x Cv = 0.024	

NB: A uniform pre-sowing seed and spray treatment of 10^{-6}M GA_3 as well as a basal dose of K_{30} was applied.

Table 36. Effect of basal N and P on leaf K content (%) of linseed cultivars at two stages of growth (Mean of four replicates)

Treatments (T) (kg/ha)	Cultivars (Cv) Parvati	Shekhar	Shubhra	Mean
		60 DAS		
N_0P_0	2.40	2.48	2.51	2.46
$N_{30}P_{10}$	2.47	2.52	2.56	2.52
$N_{60}P_{20}$	2.54	2.61	2.69	2.61
$N_{90}P_{30}$	2.57	2.62	2.72	2.64
Mean	2.50	2.56	2.62	
CD at 5%	T= NS	Cv = NS	T x Cv = NS	
		75 DAS		
N_0P_0	2.52	2.59	2.62	2.58
$N_{30}P_{10}$	2.58	2.63	2.69	2.63
$N_{60}P_{20}$	2.64	2.70	2.78	2.71
$N_{90}P_{30}$	2.62	2.65	2.80	2.69
Mean	2.59	2.64	2.72	
CD at 5%	T = NS	Cv = NS	T x Cv = NS	

NB: A uniform pre-sowing seed and spray treatment of 10^{-6}M GA_3 as well as a basal dose of K_{30} was applied.

NS = Non-significant

Table 37. Effect of basal N and P on capsules per plant and seeds per capsule of linseed cultivars at harvest (Mean of four replicates)

Treatments (T) (kg/ha)	Cultivars (Cv) Parvati	Shekhar	Shubhra	Mean
	Capsules per plant			
N_0P_0	66.67	61.00	71.00	66.22
$N_{30}P_{10}$	83.00	76.67	98.67	86.11
$N_{60}P_{20}$	110.00	106.33	127.00	114.44
$N_{90}P_{30}$	103.67	109.00	118.00	110.22
Mean	90.84	88.25	103.67	
CD at 5%	T= 4.58	Cv = 3.97	T x Cv = 7.93	
	Seeds per capsule			
N_0P_0	7.42	7.73	8.16	7.77
$N_{30}P_{10}$	7.96	8.49	8.61	8.35
$N_{60}P_{20}$	8.98	9.10	9.38	9.15
$N_{90}P_{30}$	8.29	8.57	8.83	8.56
Mean	8.16	8.47	8.75	
CD at 5%	T = NS	Cv = NS	T x Cv = NS	

NB: A uniform pre-sowing seed and spray treatment of 10^{-6}M GA_3 as well as a basal dose of K_{30} was applied.

NS = Non-significant

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4.2.3.3 1000-seed weight

Treatment $N_{90}P_{30}$ gave the maximum value for this parameter, however its effect was at par with that of $N_{60}P_{20}$ and $N_{30}P_{10}$. Treatment $N_{90}P_{30}$ increased 1000-seed weight by 4.5% over N_0P_0.

As noted earlier, cultivar differences and the interaction (treatment x cultivar) effect were not significant (Table 38).

4.2.3.4 Seed yield per plant

Treatment $N_{60}P_{20}$ gave the maximum value, with $N_{90}P_{30}$ giving equal value. Treatment $N_{60}P_{20}$ enhanced seed yield per plant by 83.3% over N_0P_0.

Among cultivars, Shubhra gave the maximum seed yield. It was followed by Shekhar and Parvati. Cultivar Shubhra gave 10.5% higher seed yield than Parvati which gave the least value.

Among interactions, $N_{60}P_{20}$ x Shubhra gave maximum value. However, its effect was equalled by that of $N_{90}P_{30}$ x Shubhra (or Shekhar). Interaction $N_{60}P_{20}$ x Shubhra increased seed yield per plant by 104.8% over N_0P_0 x Parvati which gave the lowest value (Table 38).

4.2.3.5 Biological yield per plant

Treatment $N_{60}P_{20}$ gave the maximum value, however its effect was at par with that of $N_{90}P_{30}$. Treatment $N_{60}P_{20}$ gave 77.2% higher value than N_0P_0.

Among cultivars, Shubhra performed best. It was followed by Parvati and Shekhar. Shubhra gave 12.1% higher value than Parvati which gave the lowest value.

Interaction $N_{60}P_{20}$ x Shubhra gave the maximum value, with its effect being at par with that of $N_{90}P_{30}$ x Shubhra. Interaction $N_{60}P_{20}$ x Shubhra gave 100.7% more biological matter per plant than N_0P_0 x Parvati which gave the minimum value (Table 39).

4.2.3.6 Harvest index

The effect of nutrient combinations and cultivar differences alone as well as in combination were not significant (Table 39).

Table 38. Effect of basal N and P on 1000-seed weight and seed yield per plant of linseed cultivars at harvest (Mean of four replicates)

Treatments (T) (kg/ha)	Cultivars (Cv)			Mean
	Parvati	Shekhar	Shubhra	
		1000-seed weight (g)		
N_0P_0	8.09	7.97	8.12	8.06
$N_{30}P_{10}$	8.17	8.05	8.23	8.15
$N_{60}P_{20}$	8.31	8.37	8.41	8.36
$N_{90}P_{30}$	8.43	8.32	8.52	8.42
Mean	8.25	8.18	8.32	
CD at 5%	T= 0.33	Cv = NS	T x Cv = NS	
		Seed yield per plant (g)		
N_0P_0	2.68	2.73	2.86	2.76
$N_{30}P_{10}$	3.71	3.67	3.98	3.79
$N_{60}P_{20}$	4.82	4.88	5.49	5.06
$N_{90}P_{30}$	4.75	4.92	5.31	4.99
Mean	3.99	4.05	4.41	
CD at 5%	T = 0.33	Cv = 0.29	T x Cv = 0.57	

NB: A uniform pre-sowing seed and spray treatment of 10^{-6}M GA_3 as well as a basal dose of K_{30} was applied.

NS = Non-significant

Table 39. Effect of basal N and P on biological yield per plant and harvest index of linseed cultivars at harvest (Mean of four replicates)

Treatments (T) (kg/ha)	Cultivars (Cv)			Mean
	Parvati	Shekhar	Shubhra	
	Biological yield per plant (g)			
N_0P_0	10.03	9.92	10.92	10.29
$N_{30}P_{10}$	13.94	13.30	15.07	14.10
$N_{60}P_{20}$	17.38	17.19	20.13	18.23
$N_{90}P_{30}$	17.08	17.23	19.39	17.90
Mean	14.61	14.41	16.38	
CD at 5%	T= 1.33	Cv = 1.16	T x Cv = 2.31	
	Harvest index (%)			
N_0P_0	26.72	27.52	26.19	26.81
$N_{30}P_{10}$	26.61	27.59	26.41	26.87
$N_{60}P_{20}$	27.73	28.39	27.27	27.80
$N_{90}P_{30}$	27.81	28.55	27.39	27.92
Mean	27.22	28.01	26.82	
CD at 5%	T = NS	Cv = NS	T x Cv = NS	

NB: A uniform pre-sowing seed and spray treatment of 10^{-6}M GA_3 as well as a basal dose of K_{30} was applied.

NS = Non-significant

4.2.3.7 Oil content

The effect of nutrient combinations and their interaction with cultivars on oil content as also cultivar differences were not significant (Table 40).

4.2.3.8 Oil yield per plant

Treatment $N_{60}P_{20}$ proved best, with $N_{90}P_{30}$ giving equal value. Treatment $N_{60}P_{20}$ increased oil yield per plant by 97.3% over N_0P_0.

Cultivar Shubhra gave the maximum value, however it was followed by Shekhar and Parvati. Shubhra gave 14.8% higher oil yield than Parvati which gave the lowest value.

Among interactions $N_{60}P_{20}$ x Shubhra gave the maximum value. However, its effect was at par with that of $N_{90}P_{30}$ x Shubhra. Interaction $N_{60}P_{20}$ x Shubhra gave 130.3% higher value than N_0P_0 x Parvati which gave the lowest value (Table 40).

4.2.3.9 Iodine value

The effect of treatments on iodine value and cultivar differences were significant. However, interaction effect was not significant (Table 41)

Treatment N_0P_0 gave the maximum iodine value, with $N_{30}P_{10}$ giving equal value. Treatment $N_{60}P_{30}$ gave only 7.5% less iodine value than N_0P_0.

Among cultivars, Shekhar gave the maximum value for this parameter. Cultivar Shubhra exhibited only 5.3% less value than Shekhar.

The interaction effect on iodine value was not significant (Table 41).

4.2.3.10 Fibre yield per plant

Treatment $N_{60}P_{20}$ proved best, with $N_{90}P_{30}$ giving equal value. Treatment $N_{60}P_{20}$ gave 78.7% higher value than N_0P_0.

Cultivar Shubhra, equalled by Parvati, gave the maximum value. Shubhra increased this parameter by 10.5% over Shekhar which gave the lowest value.

Interaction $N_{60}P_{20}$ x Shubhra gave the maximum value, with its effect being at par with that of $N_{90}P_{30}$ x Shubhra (or Parvati or Shekhar) and $N_{60}P_{20}$ x Parvati (or Shekhar). Interaction $N_{60}P_{20}$ x Shubhra gave 86.8% higher value than N_0P_0 x Parvati which gave the lowest value (Table 42).

Table 40. Effect of basal N and P on oil content and oil yield per plant of linseed cultivars at harvest (Mean of four replicates)

Treatments (T) (kg/ha)	Cultivars (Cv) Parvati	Shekhar	Shubhra	Mean
	Oil content (%)			
N_0P_0	37.17	37.96	38.24	37.79
$N_{30}P_{10}$	38.41	39.29	39.57	39.09
$N_{60}P_{20}$	39.76	40.13	41.79	40.56
$N_{90}P_{30}$	39.83	39.82	41.17	40.27
Mean	38.79	39.30	40.19	
CD at 5%	T= NS	Cv = NS	T x Cv = NS	
	Oil yield per plant (g)			
N_0P_0	0.996	1.036	1.094	1.042
$N_{30}P_{10}$	1.425	1.442	1.575	1.482
$N_{60}P_{20}$	1.916	1.958	2.294	2.056
$N_{90}P_{30}$	1.892	1.959	2.186	2.012
Mean	1.557	1.599	1.787	
CD at 5%	T = 0.18	Cv = 0.16	T x Cv = 0.31	

NB: A uniform pre-sowing seed and spray treatment of 10^{-6}M GA_3 as well as a basal dose of K_{30} was applied.

NS = Non-significant

Table 41. Effect of basal N and P on iodine value of linseed cultivars at harvest (Mean of four replicates)

Treatments (T) (kg/ha)	Cultivars (Cv)			Mean
	Parvati	Shekhar	Shubhra	
		Iodine value		
N_0P_0	186.39	210.27	192.75	196.47
$N_{30}P_{10}$	179.57	198.93	187.64	188.71
$N_{60}P_{20}$	170.13	187.41	179.00	178.85
$N_{90}P_{30}$	174.40	187.62	183.25	181.76
Mean	177.62	196.06	185.66	
CD at 5%	T= 11.27	Cv = 9.76	T x Cv = NS	

NB: A uniform pre-sowing seed and spray treatment of 10^{-6}M GA_3 as well as a basal dose of K_{30} was applied.

NS = Non-significant

Table 42. Effect of basal N and P on fibre yield per plant of linseed cultivars at harvest (Mean of four replicates)

Treatments (T) (kg/ha)	Cultivars (Cv) Parvati	Shekhar	Shubhra	Mean
	Fibre yield per plant (g)			
N_0P_0	0.958	0.923	0.972	0.951
$N_{30}P_{10}$	1.476	1.377	1.496	1.450
$N_{60}P_{20}$	1.737	1.571	1.790	1.699
$N_{90}P_{30}$	1.749	1.592	1.783	1.708
Mean	1.480	1.366	1.510	
CD at 5%	T= 0.148	Cv = 0.129	T x Cv = 0.257	

NB: A uniform pre-sowing seed and spray treatment of 10^{-6}M GA_3 as well as a basal dose of K_{30} was applied.

4.2.3.11 Lodging

The effect of treatments on this parameter was not significant.

Cultivar differences were also not significant.

Among interactions, $N_{60}P_{20}$ x Shubhra exhibited the maximum lodging, however, its effect was at par by that of the most interactions. Interaction $N_{60}P_{20}$ x Shubhra gave 16.8% higher value than $N_{30}P_{10}$ x Shekhar which gave the lowest value (Table 43).

4.3 Experiment 3

The objective of this factorial randomized experiment was to enhance the performance of the three better performing linseed cultivars (Parvati, Shekhar and Shubhra) further by spray treatment of Ca in the presence of the uniform best pre-sowing seed and foliar treatment of GA_3 (10^{-6}M) and nutrient dose ($N_{60}P_{20}$ with K_{30}) emanated from the data of Experiments 1 and 2. The parameters studied at 60 and 75 DAS were kept the same as in Experiment 1. In addition, leaf Ca content was included in the list of parameters. The results (Tables 44-62) are summarized below.

4.3.1 Growth characteristics

The effect of Ca treatments and their interactions with cultivars on all growth characteristics studied at 60 and 75 DAS, as also cultivar differences, were significant (Tables 44-48).

4.3.1.1 Height per plant

Of foliar treatments, Ca_2 proved best at both stages, with its effect being at par with that of Ca_3. Treatment Ca_2 gave 16.5 and 15.7% higher value at 60 and 75 DAS respectively than the no Ca spray treatment (Ca_0).

Cultivars Shubhra and Shekhar, being at par, gave higher value than Parvati at both stages. Shubhra gave 3.8 and 7.2% higher value at 60 and 75 DAS respectively than Parvati which gave the lowest value.

Interaction Ca_3 x Shubhra gave the maximum value at both stages. However, its effect was at par with that of Ca_3 x Shekhar and Ca_2 x Shubhra (or Shekhar) at each stage. Interaction Ca_2 x Shubhra gave 24.8 and 23.4% higher value at 60 and 75 DAS respectively than Ca_0 x Parvati which gave the lowest value (Table 44).

Table 43. Effect of basal N and P on lodging of linseed cultivars at harvest (Mean of four replicates)

Treatments (T) (kg/ha)	Cultivars (Cv)			Mean
	Parvati	Shekhar	Shubhra	
		Lodging (%)		
N_0P_0	38.0	33.3	35.0	35.4
$N_{30}P_{10}$	37.7	32.7	37.0	35.8
$N_{60}P_{20}$	35.0	38.0	39.3	37.4
$N_{90}P_{30}$	37.3	35.0	36.7	36.3
Mean	37.0	34.8	37.0	
CD at 5%	T= NS	Cv = NS	T x Cv = 5.63	

NB: A uniform pre-sowing seed and spray treatment of 10^{-6}M GA_3 as well as a basal dose of K_{30} was applied.

NS = Non-significant

Table 44. Effect of foliar application of Ca on height per plant (cm) of linseed cultivars at two stages of growth (Mean of four replicates)

Treatments (T) (kg/ha)	Cultivars (Cv)			Mean
	Parvati	Shekhar	Shubhra	
		60 DAS		
Ca_0	54.8	56.5	58.0	56.4
Ca_1	60.2	64.6	61.3	62.0
Ca_2	63.0	68.4	65.7	65.7
Ca_3	64.1	69.1	66.2	66.5
Mean	60.5	64.7	62.8	
CD at 5%	T= 2.42	Cv = 2.10	T x Cv = 4.19	
		75 DAS		
Ca_0	64.4	66.4	69.7	66.8
Ca_1	69.7	74.6	72.6	72.2
Ca_2	74.3	78.2	79.5	77.3
Ca_3	76.3	80.4	82.8	79.8
Mean	71.2	73.9	76.3	
CD at 5%	T = 2.95	Cv = 2.56	T x Cv = 5.11	

NB: A uniform pre-sowing seed and foliar treatment of 10^{-6}M GA_3 as well as a basal dose of $N_{60}P_{20}K_{30}$ was applied.

4.3.1.2 Leaf area per plant

Treatment Ca_2 proved best at both stages. Its effect was followed by that of Ca_3 at each growth stage. Treatment Ca_2 gave 27.9 and 22.8% higher value at 60 and 75 DAS respectively than Ca_0.

Among cultivars, Shubhra gave the maximum value at each stage, with Parvati at 60 DAS and Shekhar at 75 DAS following it. Shubhra gave 5.9 and 7.3% higher value at 60 and 75 DAS respectively than Parvati which gave the minimum value.

Interaction Ca_2 x Shubhra proved best at both stages. Its effect was followed at 60 DAS but equalled at 75 DAS by that of Ca_3 x Shubhra. Interaction Ca_2 x Shubhra gave 37.3 and 30.0% higher value at 60 and 75 DAS respectively than Ca_0 x Parvati which gave the lowest value (Table 45).

4.3.1.3 Leaf area index

Spray treatment Ca_2, followed by Ca_3, gave the maximum value at each growth stage. Treatment Ca_2 gave 27.7 and 22.8% higher value at 60 and 75 DAS respectively than Ca_0.

Of cultivars, Shubhra surpassed others at both stages. It was followed by Parvati at 60 DAS and Shekhar and Parvati at 75 DAS. Cultivar Shubhra gave 5.5 and 7.3% higher value at 60 and 75 DAS respectively than Parvati which gave the minimum value at 75 DAS.

Among interactions, Ca_2 x Shubhra proved best at 60 and 75 DAS. Its effect was followed at 60 DAS but equalled at 75 DAS by that of Ca_3 x Shubhra. Interaction Ca_2 x Shubhra gave 37.3 and 29.9% higher value at 60 and 75 DAS respectively than Ca_0 x Parvati which gave the lowest value (Table 46).

4.3.1.4 Fresh weight per plant

Of spray treatments, Ca_2 gave the maximum value at both stages, with its effect was equalled at 60 DAS and followed at 75 DAS by that of Ca_3. Treatment Ca_2 gave 62.5 and 51.4% higher value at 60 and 75 DAS respectively than Ca_0.

Cultivar Shubhra, followed by Shekhar, performed the best at each sampling stage. Shubhra gave 31.7 and 30.4% higher value at 60 and 75 DAS respectively than Parvati which gave the lowest value.

Table 45. Effect of foliar application of Ca on leaf area per plant (cm^2) of linseed cultivars at two stages of growth (Mean of four replicates)

Treatments (T) (kg/ha)	Cultivars (Cv)			Mean
	Parvati	Shekhar	Shubhra	
		60 DAS		
Ca_0	174.58	170.26	183.32	176.05
Ca_1	196.86	188.92	209.71	198.50
Ca_2	220.49	215.12	239.64	225.08
Ca_3	224.00	201.36	227.13	217.49
Mean	203.98	198.42	215.95	
CD at 5%	T= 4.12	Cv = 3.57	T x Cv = 7.13	
		75 DAS		
Ca_0	341.18	336.53	351.47	343.06
Ca_1	358.31	364.76	389.53	370.87
Ca_2	411.62	408.78	443.39	421.26
Ca_3	394.20	411.00	430.18	411.79
Mean	376.33	380.27	403.64	
CD at 5%	T = 8.94	Cv = 7.75	T x Cv = 15.49	

NB: A uniform pre-sowing seed and foliar treatment of 10^{-6}M GA_3 as well as a basal dose of $N_{60}P_{20}K_{30}$ was applied.

Table 46. Effect of foliar application of Ca on leaf area index of linseed cultivars at two stages of growth (Mean of four replicates)

Treatments (T) (kg/ha)	Cultivars (Cv)			Mean
	Parvati	Shekhar	Shubhra	
		60 DAS		
Ca_0	5.33	5.20	5.60	5.38
Ca_1	6.01	5.77	6.41	6.06
Ca_2	6.73	6.57	7.32	6.87
Ca_3	6.84	6.15	6.93	6.64
Mean	6.23	5.92	6.57	
CD at 5%	T= 0.15	Cv = 0.13	T x Cv = 0.26	
		75 DAS		
Ca_0	10.42	10.28	10.74	10.48
Ca_1	10.94	11.14	11.90	11.33
Ca_2	12.57	12.49	13.54	12.87
Ca_3	12.04	12.55	13.14	12.58
Mean	11.49	11.62	12.33	
CD at 5%	T = 0.27	Cv = 0.24	T x Cv = 0.47	

NB: A uniform pre-sowing seed and foliar treatment of 10^{-6}M GA_3 as well as a basal dose of $N_{60}P_{20}K_{30}$ was applied.

Interaction Ca_2 x Shubhra gave the maximum value at both stages with its effect being at par with that of Ca_3 x Shubhra. Interaction Ca_2 x Shubhra gave 110.4 and 97.8% higher value at 60 and 75 DAS respectively than Ca_0 x Parvati which gave the lowest value (Table 47).

4.3.1.5 Dry weight per plant

Of spray treatments, Ca_2 proved best at both stages, with Ca_3 giving equal value. Treatment Ca_2 gave 49.8 and 34.3% higher value at 60 and 75 DAS respectively than Ca_0.

Cultivar Shubhra, followed by Shekhar, gave the maximum value at both stages. Cultivar Shubhra gave 27.2 and 33.1% higher value at 60 and 75 DAS respectively than Parvati which gave the lowest value.

Interaction Ca_2 x Shubhra gave the maximum value at both stages, with its effect being at par with that of Ca_3 x Shubhra. Interaction Ca_2 x Shubhra gave 80.8 and 78.2% higher value at 60 and 75 DAS respectively than Ca_0 x Parvati which gave the lowest value (Table 48).

4.3.2 Physiological and biochemical parameters

The effect of Ca treatments on all physiological and biochemical parameters and cultivar differences, alone as well as in combination, were significant at both stages, except net photosynthetic rate and leaf P and K content at 75 DAS. However, treatments and their interactions with cultivars did not vary with regard to P_N and leaf P and K content at 60 DAS (Tables 49-55)

4.3.2.1 Net photosynthetic rate

Spray treatments did not vary in respect of this parameter at both stages.

Cultivar Shubhra gave the maximum value at 60 DAS, with Shekhar giving equal value. Shubhra gave 11.6% higher value at 60 DAS than Parvati which gave the lowest value. Cultivar differences were at par at 75 DAS.

As mentioned above, the effect of treatment x cultivar interactions was at par at each stage (Table 49).

Table 47. Effect of foliar application of Ca on fresh weight per plant (g) of linseed cultivars at two stages of growth (Mean of four replicates)

Treatments (T) (kg/ha)	Cultivars (Cv)			Mean
	Parvati	Shekhar	Shubhra	
		60 DAS		
Ca_0	12.73	14.57	16.25	14.52
Ca_1	16.56	18.39	21.14	18.70
Ca_2	20.15	23.83	26.79	23.59
Ca_3	19.32	23.91	26.36	23.20
Mean	17.19	20.18	22.64	
CD at 5%	T= 1.43	Cv = 1.24	T x Cv = 2.47	
		75 DAS		
Ca_0	18.27	21.30	23.64	21.07
Ca_1	22.11	25.51	29.28	25.63
Ca_2	27.66	31.86	36.14	31.89
Ca_3	27.75	28.74	35.83	30.77
Mean	23.95	26.85	31.22	
CD at 5%	T = 1.23	Cv = 1.07	T x Cv = 2.13	

NB: A uniform pre-sowing seed and foliar treatment of 10^{-6}M GA_3 as well as a basal dose of $N_{60}P_{20}K_{30}$ was applied.

Table 48. Effect of foliar application of Ca on dry weight per plant (g) of linseed cultivars at two stages of growth (Mean of four replicates)

Treatments (T) (kg/ha)	Cultivars (Cv)			Mean
	Parvati	Shekhar	Shubhra	
		60 DAS		
Ca_0	2.92	2.81	3.59	3.11
Ca_1	3.53	3.54	4.47	3.85
Ca_2	4.13	4.58	5.28	4.66
Ca_3	3.97	4.09	5.19	4.42
Mean	3.64	3.76	4.63	
CD at 5%	T= 0.36	Cv = 0.32	T x Cv = 0.63	
		75 DAS		
Ca_0	4.12	4.83	5.29	4.75
Ca_1	4.92	5.67	6.41	5.63
Ca_2	5.28	6.53	7.34	6.38
Ca_3	5.36	6.02	7.15	6.18
Mean	4.92	5.76	6.55	
CD at 5%	T = 0.28	Cv = 0.25	T x Cv = 0.49	

NB: A uniform pre-sowing seed and foliar treatment of 10^{-6}M GA_3 as well as a basal dose of $N_{60}P_{20}K_{30}$ was applied.

Table 49. Effect of foliar application of Ca on net photosynthetic rate [μmol (CO_2)/m^2/s] of linseed cultivars at two stages of growth (Mean of four replicates)

Treatments (T) (kg/ha)	Cultivars (Cv)			Mean
	Parvati	Shekhar	Shubhra	
		60 DAS		
Ca_0	16.06	16.82	17.31	16.73
Ca_1	16.57	17.12	17.66	17.12
Ca_2	17.13	18.48	19.91	18.51
Ca_3	17.20	18.29	19.86	18.45
Mean	16.74	17.68	18.69	
CD at 5%	T= NS	Cv = 1.94	T x Cv = NS	
		75 DAS		
Ca_0	18.54	19.10	19.25	19.96
Ca_1	18.82	19.36	19.58	19.25
Ca_2	20.04	20.79	21.69	20.84
Ca_3	20.19	20.51	21.47	20.72
Mean	19.40	19.94	2.50	
CD at 5%	T = NS	Cv = NS	T x Cv = NS	

NB: A uniform pre-sowing seed and foliar treatment of 10^{-6}M GA_3 as well as a basal dose of $N_{60}P_{20}K_{30}$ was applied.

NS = Non-significant

4.3.2.2 Carbonic anhydrase activity

Spray treatment Ca_2 proved best at both stages, with Ca_3 giving equal value. Treatment Ca_2 improved CA activity by 14.3 and 11.2% at 60 and 75 DAS respectively over Ca_0.

Regarding cultivars, Shubhra, followed by Shekhar, performed best at each stage. Shubhra gave 11.8 and 9.2% higher value at 60 and 75 DAS respectively than Parvati which exhibited the minimum activity.

Among interactions, Ca_3 x Shubhra gave the maximum value at each stage, with its effect being at par with that of Ca_2 x Shubhra. Interaction Ca_2 x Shubhra gave 26.4 and 22.9% higher value at 60 and 75 DAS respectively than Ca_0 x Parvati which gave the lowest value (Table 50).

4.3.2.3 Leaf chlorophyll content

Spray treatment Ca_2 gave the maximum value at each sampling stage, with Ca_3 giving equal value. Treatment Ca_2 gave 20.6 and 13.5% higher value at 60 and 75 DAS respectively than Ca_0.

Cultivar Shubhra, followed by Shekhar, proved best at both stages. Cultivar Shubhra gave 3.3 and 2.7% higher value at 60 and 75 DAS respectively than Parvati which gave the lowest value.

Of interactions, Ca_2 x Shubhra gave the maximum value at both stages. However, its effect was at par with that of Ca_3 x Shubhra at 60 DAS and also with that of Ca_2 x Shekhar and Ca_3 x Shekhar at 75 DAS. Interaction Ca_2 x Shubhra gave 23.6 and 16.5% higher value at 60 and 75 DAS respectively than Ca_0 x Parvati which gave the lowest value (Table 51).

4.3.2.4 Leaf N content

Spray treatment Ca_3 gave the maximum value for leaf N content at both stages. However, its effect was at par with that of Ca_2 at 60 DAS and also with that of Ca_1 at 75 DAS. Treatment Ca_2 gave 21.1 and 18.9% higher value at 60 and 75 DAS respectively than Ca_0.

Among cultivars, Shubhra gave the maximum value at both stages. It was followed at 60 DAS but equalled at 75 DAS by Shekhar. Shubhra gave 11.1 and

Table 50. Effect of foliar application of Ca on carbonic anhydrase activity [μmol (CO_2)/kg (f.m.)/s] of linseed cultivars at two stages of growth (Mean of four replicates)

Treatments (T) (kg/ha)	Cultivars (Cv)			Mean
	Parvati	Shekhar	Shubhra	
		60 DAS		
Ca_0	359.29	385.41	381.60	375.43
Ca_1	379.03	396.17	419.52	398.24
Ca_2	398.69	435.20	454.17	429.35
Ca_3	397.80	439.71	460.05	432.52
Mean	383.70	414.12	428.84	
CD at 5%	T= 9.59	Cv = 8.30	T x Cv = 16.59	
		75 DAS		
Ca_0	429.00	458.28	463.70	450.33
Ca_1	451.27	472.54	483.16	468.99
Ca_2	478.35	497.11	527.20	500.89
Ca_3	481.21	502.37	534.41	506.00
Mean	459.96	482.58	502.12	
CD at 5%	T = 11.13	Cv = 9.64	T x Cv = 19.27	

NB: A uniform pre-sowing seed and foliar treatment of 10^{-6}M GA_3 as well as a basal dose of $N_{60}P_{20}K_{30}$ was applied.

Table 51. Effect of foliar application of Ca on leaf chlorophyll content (mg/g f.m.) of linseed cultivars at two stages of growth (Mean of four replicates)

Treatments (T) (kg/ha)	Cultivars (Cv)			Mean
	Parvati	Shekhar	Shubhra	
		60 DAS		
Ca_0	1.342	1.351	1.358	1.350
Ca_1	1.431	1.439	1.484	1.451
Ca_2	1.596	1.628	1.659	1.628
Ca_3	1.588	1.620	1.652	1.620
Mean	1.489	1.510	1.538	
CD at 5%	T= 0.016	Cv = 0.014	T x Cv = 0.027	
		75 DAS		
Ca_0	1.535	1.548	1.569	1.551
Ca_1	1.598	1.631	1.655	1.628
Ca_2	1.739	1.755	1.788	1.761
Ca_3	1.730	1.749	1.773	1.751
Mean	1.651	1.671	1.696	
CD at 5%	T = 0.023	Cv = 0.020	T x Cv = 0.039	

NB: A uniform pre-sowing seed and foliar treatment of 10^{-6}M GA_3 as well as a basal dose of $N_{60}P_{20}K_{30}$ was applied.

15.5% higher value at 60 and 75 DAS respectively than Parvatri which gave the lowest value.

Interaction Ca_3 x Shubhra gave the maximum value at each sampling stage. However, its effect was at par with that of Ca_2 x Shubhra at 60 DAS and also with that of Ca_2 x Shekhar, Ca_3 x Shekhar, Ca_1 x Shubhra, Ca_3 x Parvati, Ca_2 x Parvati, Ca_1 x Shekhar and Ca_0 x Shubhra at 75 DAS. Interaction Ca_2 x Shubhra gave 35.5 and 36.9% higher value at 60 and 75 DAS respectively than Ca_0 x Parvati which gave the lowest value (Table 52).

4.3.2.5 Leaf P content

The effect of spray treatments on this parameter was not significant at both stages.

Cultivar Shubhra gave the maximum value at 60 DAS, with Shekhar giving equal value. At this stage, cultivar Shubhra gave 20.8% higher value than Parvati which gave the lowest value. At 75 DAS, cultivars, however, did not vary.

Interaction effect on this parameter was not significant at both stages (Table 53).

4.3.2.6 Leaf K content

The effect of spray treatment was not significant at each stage.

At 60 DAS, cultivar Shubhra gave the maximum value, with Shekhar giving equal value. At this stage, cultivar Shubhra gave 7.1% higher value than Parvati which gave the lowest value. Cultivars were equal at 75 DAS.

Interaction effect was not significant at each stage (Table 54).

4.3.2.7 Leaf Ca content

Spray treatment Ca_3 gave the maximum value at both stages, with Ca_2 giving equal value. Treatment Ca_2 gave 60.0 and 61.1% higher value at 60 and 75 DAS respectively than Ca_0.

Cultivar Shubhra, followed by Shekhar, gave the maximum value at both stages. Cultivar Shubhra gave 15.4 and 27.3% higher value at 60 and 75 DAS respectively than Parvati which gave the lowest value.

Table 52. Effect of foliar application of Ca on leaf N content (%) of linseed cultivars at two stages of growth (Mean of four replicates)

Treatments (T) (kg/ha)	Cultivars (Cv)			Mean
	Parvati	Shekhar	Shubhra	
		60 DAS		
Ca_0	1.69	1.72	1.84	1.75
Ca_1	1.84	1.86	1.97	1.89
Ca_2	1.98	2.09	2.29	2.12
Ca_3	2.07	2.11	2.34	2.17
Mean	1.90	1.95	2.11	
CD at 5%	T= 0.12	Cv = 0.10	T x Cv = 0.20	
		75 DAS		
Ca_0	1.98	2.13	2.26	2.12
Ca_1	2.10	2.29	2.41	2.27
Ca_2	2.34	2.52	2.71	2.52
Ca_3	2.38	2.49	2.77	2.55
Mean	2.20	2.36	2.54	
CD at 5%	T = 0.30	Cv = 0.26	T x Cv = 0.52	

NB: A uniform pre-sowing seed and foliar treatment of 10^{-6}M GA_3 as well as a basal dose of $N_{60}P_{20}K_{30}$ was applied.

Table 53 Effect of foliar application of Ca on leaf P content (%) of linseed cultivars at two stages of growth (Mean of four replicates)

Treatments (T) (kg/ha)	Cultivars (Cv)			Mean
	Parvati	Shekhar	Shubhra	
		60 DAS		
Ca_0	0.204	0.219	0.244	0.222
Ca_1	0.217	0.230	0.261	0.236
Ca_2	0.225	0.241	0.272	0.246
Ca_3	0.230	0.247	0.268	0.248
Mean	0.219	0.234	0.261	
CD at 5%	T= NS	Cv = 0.036	T x Cv = NS	
		75 DAS		
Ca_0	0.239	0.253	0.271	0.254
Ca_1	0.253	0.265	0.284	0.267
Ca_2	0.261	0.278	0.299	0.279
Ca_3	0.267	0.272	0.306	0.282
Mean	0.267	0.272	0.290	
CD at 5%	T = NS	Cv = NS	T x Cv = NS	

NB: A uniform pre-sowing seed and foliar treatment of 10^{-6}M GA_3 as well as a basal dose of $N_{60}P_{20}K_{30}$ was applied.

NS = Non-significant

Table 54. Effect of foliar application of Ca on leaf K content (%) of linseed cultivars at two stages of growth (Mean of four replicates)

Treatments (T) (kg/ha)	Cultivars (Cv)			Mean
	Parvati	Shekhar	Shubhra	
		60 DAS		
Ca_0	2.27	2.39	2.48	2.41
Ca_1	2.36	2.49	2.56	2.49
Ca_2	2.47	2.53	2.64	2.56
Ca_3	2.50	2.56	2.59	2.54
Mean	2.40	2.49	2.57	
CD at 5%	T= NS	Cv = 0.14	T x Cv = NS	
		75 DAS		
Ca_0	2.54	2.50	2.61	2.55
Ca_1	2.61	2.57	2.68	2.62
Ca_2	2.69	2.68	2.76	2.71
Ca_3	2.70	2.65	2.73	2.69
Mean	2.64	2.60	2.70	
CD at 5%	T = NS	Cv = NS	T x Cv = NS	

NB: A uniform pre-sowing seed and foliar treatment of 10^{-6}M GA_3 as well as a basal dose of $N_{60}P_{20}K_{30}$ was applied.

NS = Non-significant

Among interactions, Ca_3 x Shubhra gave the maximum value at both stages. However, its effect was equalled by that of Ca_2 x Shubhra at each sampling stage. Interaction Ca_2 x Shubhra gave 89.3 and 106.3% higher value at 60 and 75 DAS respectively than Ca_0 x Parvati which gave the lowest value (Table 55).

4.3.3 Yield and quality characteristics

The differences of the effect of Ca treatments and cultivars, alone as well as in combination, were significant for all yield characteristics, except seeds per capsule and oil content. However, the treatment effect on harvest index and iodine value and cultivar differences for 1000-seed weight as also treatment x cultivar effect on 1000-seed weight, harvest index and iodine value were not significant (Tables 56-62).

4.3.3.1 Capsules per plant

Treatment Ca_2 proved best. However, its effect was at par with that of Ca_3. Treatment Ca_2 enhanced capsules per plant by 62.2% over Ca_0.

Cultivar Shubhra gave the maximum value. It was followed by Parvati and Shekhar. Cultivar Shubhra gave 20.7% higher value than Parvati which gave the lowest value.

Interaction Ca_3 x Shubhra surpassed other interactions. Its effect was followed by that of Ca_2 x Shubhra. Interaction Ca_3 x Shubhra gave 88.6% higher value than Ca_0 x Parvati which gave the lowest value (Table 56).

4.3.3.2 Seeds per capsule

The effect of treatments and their interactions with cultivars on this parameter, as also cultivar differences, were not significant (Table 56).

4.3.3.3 1000-seed weight

Spray treatment Ca_2 gave the maximum value. However, its effect was at par with that of Ca_3 and Ca_1. Treatment Ca_2 improved 1000-seed weight by 4.7% over Ca_0.

Cultivars did not vary in respect of 1000-seed weight.

The treatment x cultivar effect on this parameter was not significant (Table 57).

Table 55. Effect of foliar application of Ca on leaf Ca content (%) of linseed cultivars at two stages of growth (Mean of four replicates)

Treatments (T) (kg/ha)	Cultivars (Cv)			Mean
	Parvati	Shekhar	Shubhra	
		60 DAS		
Ca_0	0.28	0.29	0.32	0.30
Ca_1	0.33	0.35	0.89	0.36
Ca_2	0.45	0.47	0.58	0.48
Ca_3	0.48	0.43	.57	0.49
Mean	0.39	0.39	0.45	
CD at 5%	T= 0.04	Cv = 0.04	T x Cv = 0.07	
		75 DAS		
Ca_0	0.32	0.35	0.41	0.36
Ca_1	0.38	0.42	0.48	0.43
Ca_2	0.51	0.56	0.66	0.58
Ca_3	0.55	0.59	0.69	0.61
Mean	0.44	0.48	0.56	
CD at 5%	T = 0.03	Cv = 0.03	T x Cv = 0.05	

NB: A uniform pre-sowing seed and foliar treatment of 10^{-6}M GA_3 as well as a basal dose of $N_{60}P_{20}K_{30}$ was applied.

Table 56. Effect of foliar application of Ca on capsules per plant and seeds per capsule of linseed cultivars at harvest (Mean of four replicates)

Treatments (T) (kg/ha)	Cultivars (Cv)			Mean
	Parvati	Shekhar	Shubhra	
		Capsules per plant		
Ca_0	73.00	69.97	81.33	74.76
Ca_1	89.00	94.33	106.67	96.67
Ca_2	110.67	112.67	148.00	123.78
Ca_3	98.09	97.92	188.42	128.14
Mean	98.09	97.92	188.42	
CD at 5%	T= 5.84	Cv = 5.06	T x Cv = 10.12	
		Seeds per capsule		
Ca_0	8.37	8.51	8.49	8.46
Ca_1	8.32	8.73	8.95	8.67
Ca_2	8.93	9.17	9.26	9.12
Ca_3	8.57	9.19	9.12	8.96
Mean	8.55	8.84	8.96	
CD at 5%	T = NS	Cv = NS	T x Cv = NS	

NB: A uniform pre-sowing seed and foliar treatment of 10^{-6}M GA_3 as well as a basal dose of $N_{60}P_{20}K_{30}$ was applied.

NS = Non-significant

Table 57. Effect of foliar application of Ca on 1000-seed weight and seed yield per plant of linseed cultivars at harvest (Mean of four replicates)

Treatments (T) (kg/ha)	Cultivars (Cv)			Mean
	Parvati	Shekhar	Shubhra	
		1000-seed weight (g)		
Ca_0	9.08	9.15	9.21	9.15
Ca_1	9.21	9.36	9.42	9.33
Ca_2	9.48	9.59	9.68	9.58
Ca_3	9.51	9.48	9.57	9.52
Mean	9.32	9.40	9.47	
CD at 5%	T= 0.38	Cv = NS	T x Cv = NS	
		Seed yield per plant (g)		
Ca_0	2.59	2.68	2.81	2.69
Ca_1	3.42	3.51	3.72	3.55
Ca_2	4.17	4.56	4.79	4.57
Ca_3	3.59	3.68	4.27	3.85
Mean	3.44	3.61	3.94	
CD at 5%	T = 0.21	Cv = 0.19	T x Cv = 0.37	

NB: A uniform pre-sowing seed and foliar treatment of 10^{-6}M GA_3 as well as a basal dose of $N_{60}P_{20}K_{30}$ was applied.

NS = Non-significant

4.3.3.4 Seed yield per plant

Spray treatment Ca_2 proved best. Its effect was followed by that of Ca_3. Treatment Ca_2 gave 69.9% higher value than Ca_0.

Cultivar Shubhra produced the maximum number of seeds per plant. It was followed by Shekhar and Parvati. Cultivar Shubhra gave 14.5% higher value than Parvati which gave the lowest value.

Interaction Ca_2 x Shubhra gave the maximum seed yield. Its effect was followed by that of Ca_2 x Shekhar. Interaction Ca_2 x Shubhra improved seed yield by 91.9% over Ca_0 x Parvati which gave the lowest value (Table 57).

4.3.3.5 Biological yield per plant

Spray treatment Ca_2 gave the maximum value for this yield parameter. Its effect was followed by that of Ca_3. Treatment Ca_2 gave 67.4% higher value than Ca_0.

Regarding cultivars, Shubhra performed best. It was followed by Shekhar. Cultivar Shubhra gave 10.7% higher value than Parvati which gave the lowest value.

Interaction Ca_2 x Shubhra gave the maximum value, with Ca_3 x Shubhra showing parity with it. Interaction Ca_2 x Shubhra gave 82.7% higher value than Ca_0 x Parvati which gave the lowest value (Table 58).

4.3.3.6 Harvest index

Effect of spray treatments on this parameter was not significant.

Cultivar Shubhra gave the maximum value, with Shekhar (or Parvati) following it. Shubhra gave 3.2% higher value than Parvati which exhibited the lowest value.

Spray treatment x cultivar interactions gave equal values (Table 58).

4.3.3.7 Oil content

The effect of spray treatments and their interactions with cultivars on this parameter as also cultivar differences were found non-significant (Table 59).

Table 58. Effect of foliar application of Ca on biological yield per plant and harvest index of linseed cultivars at harvest (Mean of four replicates)

Treatments (T) (kg/ha)	Cultivars (Cv)			Mean
	Parvati	Shekhar	Shubhra	
Biological yield per plant (g)				
Ca_0	9.78	10.16	10.37	10.10
Ca_1	12.95	13.24	13.65	13.28
Ca_2	15.65	17.06	17.87	16.86
Ca_3	13.27	13.55	15.37	14.06
Mean	12.91	13.50	14.32	
CD at 5%	T= 0.43	Cv = 0.38	T x Cv = 0.75	
Harvest index (%)				
Ca_0	26.48	26.38	27.10	26.65
Ca_1	26.41	26.51	27.25	26.72
Ca_2	26.65	26.73	27.81	27.06
Ca_3	27.05	27.16	27.78	27.33
Mean	26.65	26.70	27.49	
CD at 5%	T = NS	Cv = 0.74	T x Cv = NS	

NB: A uniform pre-sowing seed and foliar treatment of 10^{-6}M GA_3 as well as a basal dose of $N_{60}P_{20}K_{30}$ was applied.

NS = Non-significant

Table 59. Effect of foliar application of Ca on oil content and oil yield per plant of linseed cultivars at harvest (Mean of four replicates)

Treatments (T) (kg/ha)	Cultivars (Cv)			Mean
	Parvati	Shekhar	Shubhra	
	Oil content (%)			
Ca_0	38.14	37.81	38.59	38.18
Ca_1	38.32	38.11	38.47	38.30
Ca_2	39.42	38.79	39.86	39.36
Ca_3	38.51	38.82	38.84	38.72
Mean	38.60	38.38	38.94	
CD at 5%	T= NS	Cv = NS	T x Cv = NS	
	Oil yield per plant (g)			
Ca_0	0.988	1.013	1.084	1.028
Ca_1	1.311	1.338	1.431	1.360
Ca_2	1.644	1.769	1.981	1.798
Ca_3	1.383	1.429	1.658	1.490
Mean	1.332	1.387	1.539	
CD at 5%	T = 0.12	Cv = 0.11	T x Cv = 0.21	

NB: A uniform pre-sowing seed and foliar treatment of 10^{-6}M GA_3 as well as a basal dose of $N_{60}P_{20}K_{30}$ was applied.

NS = Non-significant

4.3.3.8 Oil yield per plant

Spray treatment Ca_2 gave the maximum value for oil yield per plant. However, its effect was followed by that of Ca_3. Treatment Ca_2 gave 74.9% higher value than Ca_0.

Of cultivars, Shubhra performed best. It was followed by Shekhar (or Parvati). Cultivar Shubhra gave 15.5% higher value than Parvati which gave the lowest value.

Interaction Ca_2 x Shubhra gave the maximum value. Its effect was followed by that of Ca_2 x Shekhar, Ca_3 x Shubhra, and Ca_2 x Parvati. Interaction Ca_2 x Shubhra improved oil yield by 100.7% over Ca_0 x Parvati which gave the lowest value (Table 59).

4.3.3.9 Iodine value

Only cultivar differences in respect of iodine value of the oil were significant. However, the effect of spray treatments and their interaction with cultivars on this parameter were not significant (Table 60).

Cultivar Shekhar gave the maximum value for this quality parameter. However, it was at par with Parvati which itself had parity with Shubhra. Cultivar Shubhra had only 9.1% less value than Shekhar (Table 60).

4.3.3.10 Fibre yield per plant

Spray treatment Ca_2 proved best. Its effect was at par with that of Ca_3. Treatment Ca_2 gave 85.7% higher value than Ca_0.

Of cultivars, Shubhra performed best. It was followed by Parvati and Shekhar. Cultivar Shubhra gave 4.3% higher value than Parvati which gave the minimum value.

Interaction, Ca_3 x Shubhra gave the maximum value, but its effect was equalled by that of Ca_2 x Shubhra. Interaction Ca_2 x Shubhra improved fibre yield by 99.0% over Ca_0 x Shekhar which gave the lowest value (Table 61).

4.3.3.11 Lodging

Spray treatment Ca_1 gave the maximum lodging. However, its effect was at par with that of Ca_0. Spray treatment Ca_1 enhanced lodging by 24.6% over Ca_3 which gave the minimum value.

Table 60. Effect of foliar application of Ca on iodine value of linseed cultivars at harvest (Mean of four replicates)

Treatments (T) (kg/ha)	Cultivars (Cv)			Mean
	Parvati	Shekhar	Shubhra	
		Iodine value		
Ca_0	188.31	197.25	181.61	189.06
Ca_1	185.07	189.49	176.18	183.58
Ca_2	185.69	188.28	166.28	178.74
Ca_3	181.24	188.71	166.28	178.74
Mean	185.08	190.93	173.50	
CD at 5%	T= NS	Cv = 16.07	T x Cv = NS	

NB: A uniform pre-sowing seed and foliar treatment of 10^{-6}M GA_3 as well as a basal dose of $N_{60}P_{20}K_{30}$ was applied.

NS = Non-significant

Table 61. Effect of foliar application of Ca on fibre yield per plant of linseed cultivars at harvest (Mean of four replicates)

Treatments (T) (kg/ha)	Cultivars (Cv)			Mean
	Parvati	Shekhar	Shubhra	
	Fibre yield per plant (g)			
Ca_0	0.967	0.924	0.981	0.957
Ca_1	1.465	1.471	1.529	1.488
Ca_2	1.762	1.730	1.839	1.777
Ca_3	1.766	1.732	1.868	1.789
Mean	1.490	1.464	1.554	
CD at 5%	T= 0.051	Cv = 0.045	T x Cv = 0.089	

NB: A uniform pre-sowing seed and foliar treatment of 10^{-6}M GA_3 as well as a basal dose of $N_{60}P_{20}K_{30}$ was applied.

Among cultivars, Parvati followed by Shekhar and Shubhra, gave the maximum value for lodging. Cultivar Parvati exhibited 9.2% more lodging than the minimum value giving cultivar Shubhra.

Of interactions, Ca_1 x Parvati gave the maximum value. However, its effect was at par with that of Ca_0 x Parvati and Ca_1 x Shekhar. Interaction Ca_1 x Parvati exhibited 42.2% more lodging than Ca_3 x Shubhra which gave the least value (Table 62).

4.4 Experiment 4

The aim of this factorial randomized experiment was to enhance the performance of the three better performing cultivars of linseed (Parvati, Shekhar and Shubhra) by spray treatment of Mg in presence of the uniform best pre-sowing seed and foliar treatment of GA_3 (10^{-6}M) and nutrient dose $N_{60}P_{20}K_{30}$ emanated from the data of Experiments 1 and 2. The parameters studied were kept the same as in Experiment 1, with Mg content also being estimated. The important results (Tables 63-81) are given below.

4.4.1 Growth characteristics

The effect of foliar treatments of Mg and their interactions with cultivars on all growth characteristics, as also cultivar differences, were significant at both the sampling stages (Tables 63-67).

4.4.1.1 Height per plant

Spray treatment $Mg_{0.5}$ gave the maximum value at each growth stage. However, its effect was at par at 60 DAS and followed at 75 DAS by that of Mg_1. Treatment $Mg_{0.5}$ gave 10.7 and 10.9% higher value at 60 and 75 DAS respectively than Mg_0.

Among cultivars, Shubhra performed best at both sampling stages, with Shekhar following it. Shubhra gave 9.1 and 9.4% higher value at 60 and 75 DAS respectively than Parvati which gave the lowest value.

Interaction $Mg_{0.5}$ x Shubhra proved best at each sampling stage. However, its effect was equalled by that of Mg_1 x Shubhra at both stages and also by that of $Mg_{1.5}$ x Shubhra at 60 DAS. Interaction $Mg_{0.5}$ x Shubhra gave 17.5 and 20.8% higher value at 60 and 75 DAS respectively than Mg_0 x Parvati which gave the lowest value (Table 63).

Table 62. Effect of foliar application of Ca on lodging of linseed cultivars at harvest (Mean of four replicates)

Treatments (T) kg/ha	Cultivars (Cv)			Mean
	Parvati	Shekhar	Shubhra	
		Lodging (%)		
Ca_0	32.3	29.0	31.0	30.8
Ca_1	33.7	31.3	30.7	31.9
Ca_2	30.3	30.7	27.3	29.3
Ca_3	27.0	26.0	23.7	25.6
Mean	30.8	29.3	28.2	
CD at 5%	T= 1.48	Cv = 1.28	T x Cv = 2.56	

NB: A uniform pre-sowing seed and foliar treatment of 10^{-6}M GA_3 as well as a basal dose of $N_{60}P_{20}K_{30}$was applied.

Table 63. Effect of foliar application of Mg on height per plant (cm) of linseed cultivars at two stages of growth (Mean of four replicates)

Treatments (T) (kg/ha)	Cultivars (Cv)			Mean
	Parvati	Shekhar	Shubhra	
		60 DAS		
Mg_0	61.3	62.7	64.0	62.7
$Mg_{0.5}$	68.7	67.4	72.0	69.4
$Mg_{1.0}$	66.1	65.5	74.3	68.6
$Mg_{1.5}$	63.2	64.8	72.4	66.8
Mean	64.8	65.1	70.7	
CD at 5%	T= 2.49	Cv = 2.16	T x Cv = 4.32	
		75 DAS		
Mg_0	68.2	71.1	74.6	71.3
$Mg_{0.5}$	76.6	78.2	82.4	79.1
$Mg_{1.0}$	73.4	75.7	80.0	76.4
$Mg_{1.5}$	70.1	73.5	78.6	74.1
Mean	72.1	74.6	78.9	
CD at 5%	T = 1.65	Cv = 1.43	T x Cv = 2.86	

NB: A uniform pre-sowing seed and foliar treatment of 10^{-6}M GA_3 as well as a basal dose of $N_{60}P_{20}K_{30}$ was applied.

4.4.1.2 Leaf area per plant

Spray treatment $Mg_{0.5}$ gave the maximum leaf area per plant at each stage. Its effect was followed at 60 DAS and equalled at 75 DAS by that of $Mg_{1.0}$. Treatment $Mg_{0.5}$ gave 11.5 and 9.1% higher value at 60 and 75 DAS respectively than Mg_0.

Cultivar Shubhra performed best at both stages, with Shekhar following it. Cultivar Shubhra gave 11.1 and 5.5% higher leaf area per plant at 60 and 75 DAS respectively than Parvati which gave the lowest value.

Of interactions, $Mg_{0.5}$ x Shubhra proved best at both stages. However, its effect was followed at 60 DAS and equalled at 75 DAS by that of $Mg_{1.0}$ x Shubhra. Interaction $Mg_{0.5}$ x Shubhra gave 22.7 and 12.6% higher value at 60 and 75 DAS respectively than Mg_0 x Parvati which gave the lowest value (Table 64).

4.4.1.3 Leaf area index

Spray treatment $Mg_{0.5}$ gave the maximum leaf area index at each sampling stage. Its effect was followed by that of $Mg_{1.0}$ and $Mg_{1.5}$ at 60 DAS and by that of $Mg_{1.0}$ only at 75 DAS. Treatment $Mg_{0.5}$ gave 11.5 and 9.1% higher value at 60 and 75 DAS respectively than Mg_0.

Cultivar Shubhra performed best at both sampling stages. It was followed by Shekhar at each sampling stage. Cultivar Shubhra gave 11.1 and 5.5% higher value at 60 and 75 DAS respectively than Parvati which gave the lowest value.

Among interactions, $Mg_{0.5}$ x Shubhra, being at par with $Mg_{1.0}$ x Shubhra, gave the maximum value at each stage. Interaction $Mg_{0.5}$ x Shubhra gave 22.9 and 12.6% higher value at 60 and 75 DAS respectively than Mg_0 x Parvati which gave the lowest value (Table 65).

4.4.1.4 Fresh weight per plant

Spray treatment $Mg_{0.5}$ proved best at both sampling stages, with $Mg_{1.0}$ giving equal value. Spray treatment $Mg_{0.5}$ improved fresh weight per plant by 50.4 and 30.5% at 60 and 75 DAS respectively over Mg_0.

Regarding cultivars, Shubhra performed best at each stage. However, it was followed by Shekhar at both stages. Cultivar Shubhra gave 33.0 and 28.9% higher value at 60 and 75 DAS respectively than Parvati which gave the lowest value.

Table 64. **Effect of foliar application of Mg on leaf area per plant (cm^2) of linseed cultivars at two stages of growth (Mean of four replicates)**

Treatments (T) (kg/ha)	Cultivars (Cv)			Mean
	Parvati	Shekhar	Shubhra	
		60 DAS		
Mg_0	172.17	179.60	187.49	179.75
$Mg_{0.5}$	188.73	201.39	211.32	200.48
$Mg_{1.0}$	180.22	190.14	204.51	191.62
$Mg_{1.5}$	179.10	188.38	196.78	188.09
Mean	180.06	189.88	200.03	
CD at 5%	T= 3.07	Cv = 2.66	T x Cv = 5.32	
		75 DAS		
Mg_0	362.34	358.51	369.23	363.36
$Mg_{0.5}$	388.46	392.49	408.07	396.34
$Mg_{1.0}$	381.21	386.74	411.18	393.04
$Mg_{1.5}$	372.00	380.48	398.26	383.58
Mean	376.00	379.56	396.69	
CD at 5%	T = 4.40	Cv = 3.31	T x Cv = 7.62	

NB: A uniform pre-sowing seed and foliar treatment of 10^{-6}M GA_3 as well as a basal dose of $N_{60}P_{20}K_{30}$ was applied.

Table 65. Effect of foliar application of Mg on leaf area index of linseed cultivars at two stages of growth (Mean of four replicates)

Treatments (T) (kg/ha)	Cultivars (Cv)			Mean
	Parvati	Shekhar	Shubhra	
		60 DAS		
Mg_0	5.25	5.49	5.73	5.49
$Mg_{0.5}$	5.76	6.15	6.45	6.12
$Mg_{1.0}$	5.50	5.80	6.25	5.85
$Mg_{1.5}$	5.47	5.75	6.01	5.47
Mean	5.50	5.80	6.11	
CD at 5%	T= 0.17	Cv = 0.15	T x Cv = 0.29	
		75 DAS		
Mg_0	11.07	10.95	11.28	11.10
$Mg_{0.5}$	11.87	11.99	12.46	12.11
$Mg_{1.0}$	11.64	11.81	12.56	12.00
$Mg_{1.5}$	11.36	11.62	12.17	11.72
Mean	11.49	11.59	12.12	
CD at 5%	T = 0.08	Cv = 0.07	T x Cv = 0.13	

NB: A uniform pre-sowing seed and foliar treatment of 10^{-6}M GA_3 as well as a basal dose of $N_{60}P_{20}K_{30}$ was applied.

Interactions $Mg_{0.5}$ x Shubhra and $Mg_{1.0}$ x Shubhra, being at par, gave maximum value at both sampling stages. Interaction $Mg_{0.5}$ x Shubhra increased fresh weight per plant by 105.7 and 78.0% at 60 and 75 DAS respectively over Mg_0 x Parvati which gave the lowest value (Table 66).

4.4.1.5 Dry weight per plant

Of spray treatments, $Mg_{0.5}$ gave the maximum value at both sampling stages. Its effect was followed by that of $Mg_{1.0}$ at 60 DAS and also by that of $Mg_{1.5}$ at 75 DAS. Treatment $Mg_{0.5}$ gave 37.4 and 25.8% higher value at 60 and 75 DAS respectively than Mg_0.

Among cultivars, Shubhra gave the maximum value at both stages, with Shekhar following it. Cultivar Shubhra showed an increase of 32.8 and 56.0% in dry matter production at 60 and 75 DAS respectively over Parvati which gave the lowest value.

Interaction $Mg_{0.5}$ x Shubhra proved best at both sampling stages. Its effect was equalled at 60 DAS but followed at 75 DAS by that of $Mg_{1.0}$ x Shubhra. Interaction $Mg_{0.5}$ x Shubhra enhanced dry weight per plant by 73.8 and 86.4% at 60 and 75 DAS respectively than Mg_0 x Parvati which gave the lowest value (Table 67).

4.4.2 Physiological and biochemical parameters

The effect of treatments and their interactions with cultivars on all physiological and biochemical parameters, as also cultivar differences, were significant at both stages, except leaf P content at both stages and K content at 75 DAS. However, the effect of treatments and their interactions with cultivars on leaf N content was not significant at both stages (Tables 68-74).

4.4.2.1 Net photosynthetic rate

Spray treatment $Mg_{0.5}$ gave the maximum value at both the sampling stages, with $Mg_{1.0}$ following it in their effect. Spray treatment $Mg_{0.5}$ improved net photosynthetic rate by 21.6 and 17.4% at 60 and 75 DAS respectively over Mg_0.

Among cultivars, Shubhra gave the maximum value at both sampling stages. It was at par at 60 DAS and followed at 75 DAS by Shekhar. Cultivar

Table 66. Effect of foliar application of Mg on fresh weight per plant (g) of linseed cultivars at two stages of growth (Mean of four replicates)

Treatments (T) (kg/ha)	Cultivars (Cv)			Mean
	Parvati	Shekhar	Shubhra	
		60 DAS		
Mg_0	13.51	15.30	18.29	15.70
$Mg_{0.5}$	20.34	22.69	27.79	23.61
$Mg_{1.0}$	18.82	21.76	24.37	21.65
$Mg_{1.5}$	16.47	19.00	21.52	19.00
Mean	17.29	19.69	22.99	
CD at 5%	T= 2.45	Cv = 2.13	T x Cv = 4.26	
		75 DAS		
Mg_0	19.38	22.79	26.21	22.79
$Mg_{0.5}$	25.34	29.36	34.50	29.73
$Mg_{1.0}$	27.26	30.16	32.29	29.90
$Mg_{1.5}$	23.10	26.44	29.57	26.37
Mean	23.77	27.19	30.64	
CD at 5%	T = 1.78	Cv = 1.54	T x Cv = 3.08	

NB: A uniform pre-sowing seed and foliar treatment of 10^{-6}M GA_3 as well as a basal dose of $N_{60}P_{20}K_{30}$ was applied.

Table 67. Effect of foliar application of Mg on dry weight per plant (g) of linseed cultivars at two stages of growth (Mean of four replicates)

Treatments (T) (kg/ha)	Cultivars (Cv)			Mean
	Parvati	Shekhar	Shubhra	
		60 DAS		
Mg_0	3.51	4.13	4.39	4.01
$Mg_{0.5}$	4.78	5.65	6.10	5.51
$Mg_{1.0}$	4.08	5.09	5.82	5.00
$Mg_{1.5}$	3.85	4.87	5.24	4.65
Mean	4.06	4.94	5.39	
CD at 5%	T= 0.17	Cv = 0.15	T x Cv = 0.29	
		75 DAS		
Mg_0	4.62	5.29	6.26	5.39
$Mg_{0.5}$	5.41	6.31	8.61	6.78
$Mg_{1.0}$	4.86	5.77	7.75	6.13
$Mg_{1.5}$	4.53	5.52	7.69	5.91
Mean	4.86	5.72	7.58	
CD at 5%	T = 0.25	Cv = 0.22	T x Cv = 0.43	

NB: A uniform pre-sowing seed and foliar treatment of 10^{-6}M GA_3 as well as a basal dose of $N_{60}P_{20}K_{30}$ was applied.

Shubhra gave 11.9 and 13.3% higher value at 60 and 75 DAS respectively than Parvati which gave the lowest value.

Of interactions, $Mg_{0.5}$ x Shubhra gave the maximum value at both sampling stages. However its effect was at par with that of $Mg_{0.5}$ x Shekhar and $Mg_{1.0}$ x Shubhra at 60 DAS and with that of only $Mg_{0.5}$ x Shekhar at 75 DAS. Interaction $Mg_{0.5}$ x Shubhra gave 38.5 and 29.5% higher value at 60 and 75 DAS respectively than Mg_0 x Parvati which gave the lowest value (Table 68).

4.4.2.2 Carbonic anhydrase activity

Spray treatment $Mg_{0.5}$ gave the maximum value at each stage. Its effect was equalled at 60 DAS but followed at 75 DAS by that of $Mg_{1.0}$. Treatment $Mg_{0.5}$ gave 16.0 and 15.4% higher value at 60 and 75 DAS respectively than Mg_0.

Cultivar Shubhra surpassed others at both stages, with Shekhar following it. Cultivar Shubhra increased CA activity by 12.5 and 10.0% at 60 and 75 DAS respectively over Parvati which exhibited the minimum value.

Of interactions, $Mg_{0.5}$ x Shubhra gave the maximum value at both stages. Its effect was equalled by that of $Mg_{1.0}$ x Shubhra at 60 DAS but followed by that of the same interaction and $Mg_{0.5}$ x Shekhar at 75 DAS. Interaction $Mg_{0.5}$ x Shubhra improved CA activity by 31.1 and 26.7% at 60 and 75 DAS respectively over Mg_0 x Parvati which gave the lowest value (Table 69).

4.4.2.3 Leaf chlorophyll content

Foliar spray treatment $Mg_{0.5}$ proved best at both stages, with its effect being at par with that of $Mg_{1.0}$. Spray treatment $Mg_{0.5}$ enhanced leaf chlorophyll content by 19.3 and 17.3% at 60 and 75 DAS respectively over Mg_0.

Cultivar Shubhra surpassed other cultivars at each sampling stage, with Shekhar occupying the next position. Cultivar Shubhra gave 7.2 and 8.1% higher value at 60 and 75 DAS respectively than Parvati which gave the lowest value.

Of interactions, $Mg_{0.5}$ x Shubhra proved best at both stages. However, its effect was equalled by $Mg_{1.0}$ x Shubhra at 60 DAS and also by that of $Mg_{1.5}$ x Shubhra at 75 DAS. Interaction $Mg_{0.5}$ x Shubhra improved leaf chlorophyll content by 27.3 and 27.2% at 60 and 75 DAS respectively over Mg_0 x Parvati which gave the lowest value (Table 70).

Table 68. Effect of foliar application of Mg on net photosynthetic rate [μmol (CO_2)/m^2/s] of linseed cultivars at two stages of growth (Mean of four replicates)

Treatments (T) (kg/ha)	Cultivars (Cv)			Mean
	Parvati	Shekhar	Shubhra	
		60 DAS		
Mg_0	17.65	19.29	19.74	18.89
$Mg_{0.5}$	21.29	23.18	24.45	22.97
$Mg_{1.0}$	20.37	21.59	22.76	21.57
$Mg_{1.5}$	18.54	19.81	20.16	19.50
Mean	19.46	20.97	21.78	
CD at 5%	T= 0.99	Cv = 0.86	T x Cv = 1.72	
		75 DAS		
Mg_0	20.44	21.63	22.10	21.39
$Mg_{0.5}$	23.24	25.62	26.47	25.11
$Mg_{1.0}$	21.11	23.48	25.13	23.24
$Mg_{1.5}$	20.59	22.10	23.09	21.93
Mean	21.35	23.21	24.20	
CD at 5%	T = 0.70	Cv = 0.61	T x Cv = 1.21	

NB: A uniform pre-sowing seed and foliar treatment of 10^{-6}M GA_3 as well as a basal dose of $N_{60}P_{20}K_{30}$ was applied.

Table 69. Effect of foliar application of Mg on carbonic anhydrase activity [μmol (CO_2)/kg (f.m.)/s] of linseed cultivars at two stages of growth (Mean of four replicates)

Treatments (T) (kg/ha)	Cultivars (Cv)			Mean
	Parvati	Shekhar	Shubhra	
		60 DAS		
Mg_0	397.34	417.05	463.16	425.85
$Mg_{0.5}$	472.00	489.37	521.05	494.14
$Mg_{1.0}$	463.53	476.18	507.29	482.33
$Mg_{1.5}$	423.19	439.30	483.93	448.81
Mean	439.02	455.48	493.86	
CD at 5%	T= 12.18	Cv = 10.55	T x Cv = 21.09	
		75 DAS		
Mg_0	457.00	480.42	517.14	484.85
$Mg_{0.5}$	539.22	560.00	579.18	559.47
$Mg_{1.0}$	507.83	543.71	563.59	538.38
$Mg_{1.5}$	488.64	506.35	532.07	509.02
Mean	498.17	522.62	548.00	
CD at 5%	T = 7.98	Cv = 6.92	T x Cv = 13.83	

NB: A uniform pre-sowing seed and foliar treatment of 10^{-6}M GA_3 as well as a basal dose of $N_{60}P_{20}K_{30}$ was applied.

Table 70. Effect of foliar application of Mg on leaf chlorophyll content (mg/g f.m.) of linseed cultivars at two stages of growth (Mean of four replicates)

Treatments (T) (kg/ha)	Cultivars (Cv)			Mean
	Parvati	Shekhar	Shubhra	
		60 DAS		
Mg_0	1.372	1.386	1.431	1.396
$Mg_{0.5}$	1.611	1.642	1.746	1.666
$Mg_{1.0}$	1.625	1.636	1.757	1.673
$Mg_{1.5}$	1.465	1.485	1.575	1.508
Mean	1.518	1.537	1.627	
CD at 5%	T= 0.047	Cv = 0.041	T x Cv = 0.081	
		75 DAS		
Mg_0	1.553	1.571	1.654	1.593
$Mg_{0.5}$	1.802	1.827	1.976	1.868
$Mg_{1.0}$	1.810	1.801	1.920	1.844
$Mg_{1.5}$	1.715	1.790	1.886	1.797
Mean	1.720	1.747	1.859	
CD at 5%	T = 0.061	Cv = 0.053	T x Cv = 0.105	

NB: A uniform pre-sowing seed and foliar treatment of $10^{-6}M\ GA_3$ as well as a basal dose of $N_{60}P_{20}K_{30}$ was applied.

4.4.2.4 Leaf N content

Spray treatments did not vary at each stage.

Cultivars showed parity at 60 DAS. However, cultivar Shubhra gave the maximum value at 75 DAS, with Shekhar exhibiting parity with it. Shubhra gave 10.7% higher value at 75 DAS than Parvati which gave the lowest value.

Spray treatment x cultivar interactions gave equal values at both stages (Table 71).

4.4.2.5 Leaf P content

The effect of treatments and their interactions with cultivars on this parameter, as also cultivar differences, were not significant at both stages (Table 72).

4.4.2.6 Leaf K content

Increasing levels of spray Mg decreased leaf K content at 60 DAS. The effect of spray treatment Mg_0 was at par with that of $Mg_{0.5}$ at this stage. Spray treatment $Mg_{0.5}$ gave 7.4% higher value at the above mentioned stage than $Mg_{1.5}$ which gave the least value. However, spray treatments did not differ at 75 DAS.

Among cultivars, Shubhra gave the maximum value at 60 DAS, with Shekhar (also Parvati) following it. At this stage, cultivar Shubhra gave 8.8% higher value than Parvati which gave the lowest value. However, cultivar differences were not significant at 75 DAS.

Interaction Mg_0 x Shubhra gave the maximum value for leaf K content at 60 DAS, with its effect being at par with that of $Mg_{0.5}$ x Shubhra, Mg_0 x Shekhar, and $Mg_{1.0}$ x Shubhra. At this stage, interaction $Mg_{0.5}$ x Shubhra gave 16.9% higher value than $Mg_{1.5}$ x Shekhar which gave the lowest value. However, interaction effect was not significant at 75 DAS (Table 73).

4.4.2.7 Leaf Mg content

Increasing levels of spray Mg enhanced leaf Mg content at both stages. However, the effect of spray treatment $Mg_{1.5}$ was at par with that of $Mg_{1.0}$ at both stages. Application of $Mg_{0.5}$ increased leaf Mg content by 14.3 and 11.7% at 60 and 75 DAS respectively over Mg_0.

Table 71. Effect of foliar application of Mg on leaf N content (%) of linseed cultivars at two stages of growth (Mean of four replicates)

Treatments (T) (kg/ha)	Cultivars (Cv)			Mean
	Parvati	Shekhar	Shubhra	
		60 DAS		
Mg_0	2.62	2.71	2.95	2.76
$Mg_{0.5}$	2.58	2.69	2.90	2.72
$Mg_{1.0}$	2.50	2.61	2.73	2.61
$Mg_{1.5}$	2.41	2.52	2.55	2.49
Mean	2.53	2.63	2.78	
CD at 5%	T= NS	Cv = NS	T x Cv = NS	
		75 DAS		
Mg_0	2.93	3.02	3.25	3.07
$Mg_{0.5}$	2.87	2.98	3.20	3.02
$Mg_{1.0}$	2.81	2.92	3.04	2.92
$Mg_{1.5}$	2.61	2.73	2.96	2.77
Mean	2.81	2.91	3.11	
CD at 5%	T = NS	Cv = 0.28	T x Cv = NS	

NB: A uniform pre-sowing seed and foliar treatment of 10^{-6}M GA_3 as well as a basal dose of $N_{60}P_{20}K_{30}$ was applied.

NS = Non-significant

Table 72. Effect of foliar application of Mg on leaf P content (%) of linseed cultivars at two stages of growth (Mean of four replicates)

Treatments (T) (kg/ha)	Cultivars (Cv)			Mean
	Parvati	Shekhar	Shubhra	
		60 DAS		
Mg_0	0.276	0.272	0.281	0.276
$Mg_{0.5}$	0.269	0.267	0.278	0.271
$Mg_{1.0}$	0.270	0.260	0.272	0.267
$Mg_{1.5}$	0.258	0.251	0.265	0.258
Mean	0.268	0.263	0.274	
CD at 5%	T= NS	Cv = NS	T x Cv = NS	
		75 DAS		
Mg_0	0.314	0.302	0.317	0.311
$Mg_{0.5}$	0.309	0.300	0.314	0.308
$Mg_{1.0}$	0.301	0.295	0.309	0.302
$Mg_{1.5}$	0.285	0.291	0.307	0.294
Mean	0.302	0.297	0.312	
CD at 5%	T = NS	Cv = NS	T x Cv = NS	

NB: A uniform pre-sowing seed and foliar treatment of 10^{-6}M GA_3 as well as a basal dose of $N_{60}P_{20}K_{30}$ was applied.

NS = Non-significant

Table 73. Effect of foliar application of Mg on leaf K content (%) of linseed cultivars at two stages of growth (Mean of four replicates)

Treatments (T) (kg/ha)	Cultivars (Cv)			Mean
	Parvati	Shekhar	Shubhra	
		60 DAS		
Mg_0	2.71	2.79	2.93	2.81
$Mg_{0.5}$	2.64	2.73	2.90	2.76
$Mg_{1.0}$	2.57	2.59	2.79	2.65
$Mg_{1.5}$	2.50	2.48	2.72	2.57
Mean	2.61	2.65	2.84	
CD at 5%	T= 0.11	Cv = 0.10	T x Cv = 0.19	
		75 DAS		
Mg_0	2.89	2.96	3.12	2.99
$Mg_{0.5}$	2.86	2.88	3.07	2.94
$Mg_{1.0}$	2.78	2.79	2.98	2.85
$Mg_{1.5}$	2.71	2.72	2.91	2.78
Mean	2.81	2.84	3.02	
CD at 5%	T = NS	Cv = NS	T x Cv = NS	

NB: A uniform pre-sowing seed and foliar treatment of 10^{-6}M GA_3 as well as a basal dose of $N_{60}P_{20}K_{30}$ was applied.

NS = Non-significant

Cultivar Shubhra exhibited the maximum leaf Mg content at each sampling stage. It was followed by Shekhar at 60 DAS and also by Parvati at 75 DAS. Cultivar Shubhra had 16.8 and 15.7% more leaf Mg content at 60 and 75 DAS respectively than Parvati which gave the lowest value.

Of interactions, $Mg_{1.5}$ x Shubhra gave the maximum value for leaf Mg content at both stages. Its effect was equalled by that of $Mg_{1.0}$ x Shubhra and $Mg_{0.5}$ x Shubhra at 60 DAS and by that of only $Mg_{1.0}$ x Shubhra at 75 DAS. Interaction $Mg_{0.5}$ x Shubhra gave 31.3 and 26.8% higher value at 60 and 75 DAS respectively than Mg_0 x Parvati which gave the minimum value (Table 74).

4.4.3 Yield and quality characteristics

The effect of treatments and their interactions with cultivars on all yield characteristics, as also cultivar differences, were significant, except 1000-seed weight. However, the effect of treatments on oil content and iodine value and their interactions on seeds per capsule, oil content and iodine value were not significant (Table 75-81).

4.4.3.1 Capsules per plant

Spray treatment $Mg_{0.5}$ gave the maximum number of capsules per plant. However, its effect was at par with that of $Mg_{1.0}$. Treatment $Mg_{0.5}$ increased capsules per plant by 25.3% over Mg_0.

Among cultivars, Shubhra had the maximum number of capsules per plant, with Shekhar following it. Cultivar Shubhra gave 23.2% higher value than Parvati which gave the minimum number.

Among interactions, $Mg_{0.5}$ x Shubhra gave the maximum value. However, its effect was at par with that of $Mg_{1.0}$ x Shubhra. Interaction $Mg_{0.5}$ x Shubhra gave 53.5% higher value than Mg_0 x Parvati which gave the lowest value (Table 75).

4.4.3.2 Seeds per capsule

Of foliar treatments, $Mg_{0.5}$ proved best. However, its effect was at par with that of $Mg_{1.0}$. Spray treatment $Mg_{0.5}$ enhanced seeds per capsule by 4.5% over Mg_0.

Cultivars Shubhra and Parvati, being at par, proved superior to Shekhar. Shubhra gave 2.4% higher value than Shekhar, which gave the lowest value.

Table 74. Effect of foliar application of Mg on leaf Mg content (%) of linseed cultivars at two stages of growth (Mean of four replicates)

Treatments (T) (kg/ha)	Cultivars (Cv)			Mean
	Parvati	Shekhar	Shubhra	
		60 DAS		
Mg_0	0.217	0.231	0.246	0.231
$Mg_{0.5}$	0.248	0.260	0.285	0.264
$Mg_{1.0}$	0.252	0.271	0.297	0.273
$Mg_{1.5}$	0.260	0.274	0.310	0.281
Mean	0.244	0.259	0.285	
CD at 5%	T= 0.014	Cv = 0.013	T x Cv = 0.025	
		75 DAS		
Mg_0	0.310	0.309	0.352	0.324
$Mg_{0.5}$	0.342	0.351	0.393	0.362
$Mg_{1.0}$	0.357	0.362	0.418	0.379
$Mg_{1.5}$	0.361	0.368	0.423	0.384
Mean	0.343	0.348	0.397	
CD at 5%	T = 0.011	Cv = 0.009	T x Cv = 0.019	

NB: A uniform pre-sowing seed and foliar treatment of 10^{-6}M GA_3 as well as a basal dose of $N_{60}P_{20}K_{30}$ was applied.

Table 75. Effect of foliar application of Mg on capsules per plant and seeds per capsule of linseed cultivars at harvest (Mean of four replicates)

Treatments (T) (kg/ha)	Cultivars (Cv)			Mean
	Parvati	Shekhar	Shubhra	
		Capsules per plant		
Mg_0	80.33	84.67	93.00	86.00
$Mg_{0.5}$	96.00	104.00	123.33	107.78
$Mg_{1.0}$	92.00	110.33	115.67	106.00
$Mg_{1.5}$	84.50	89.67	102.67	92.28
Mean	88.21	97.17	108.67	
CD at 5%	T= 7.28	Cv = 6.31	T x Cv = 12.61	
		Seeds per capsule		
Mg_0	9.13	8.68	8.74	8.85
$Mg_{0.5}$	9.24	9.11	9.40	9.25
$Mg_{1.0}$	9.29	9.06	9.37	9.24
$Mg_{1.5}$	9.02	8.86	9.05	8.98
Mean	9.17	8.93	9.14	
CD at 5%	T = 0.18	Cv = 0.16	T x Cv = NS	

NB: A uniform pre-sowing seed and foliar treatment of 10^{-6}M GA_3 as well as a basal dose of $N_{60}P_{20}K_{30}$ was applied.

NS = Non-significant

Spray treatment x cultivar interactions did not vary in their effect on this parameter (Table 75).

4.4.3.3 1000-seed weight

The effect of treatments and their interactions with cultivars on the test weight of seeds, as also cultivar differences, were not significant (Table 76).

4.4.3.4 Seed yield per plant

Treatment $Mg_{0.5}$ was found most effective in enhancing seed yield. Its effect was followed by that of $Mg_{1.0}$. Treatment $Mg_{0.5}$ increased seed yield by 24.8% over Mg_0.

Cultivar Shubhra followed by Shekhar, gave the maximum value. Shubhra gave 19.1% higher seed yield than Parvati which gave the lowest value.

Among interactions, $Mg_{0.5}$ x Shubhra gave the maximum value. Its effect was followed by that of $Mg_{1.0}$ x Shubhra. Interaction $Mg_{0.5}$ x Shubhra gave 48.3% higher seed yield than Mg_0 x Parvati which gave the lowest value (Table 76).

4.4.3.5 Biological yield per plant

Of foliar treatments, $Mg_{0.5}$ proved best. However, its effect was equalled by that of $Mg_{1.0}$. Treatment $Mg_{0.5}$ gave 21.2% higher value than Mg_0.

Regarding cultivars, Shubhra gave the maximum value, with Shekhar giving equal value. Cultivar Shubhra gave 18.3% higher biological yield than Parvati which gave the lowest value.

Interaction $Mg_{0.5}$ x Shubhra gave the maximum value. However, its effect was at par with that of $Mg_{1.0}$ x Shubhra, $Mg_{0.5}$ x Shekhar and $Mg_{1.0}$ x Shekhar. Interaction $Mg_{0.5}$ x Shubhra gave 42.8% higher value than Mg_0 x Parvati which gave the lowest value (Table 77).

4.4.3.6 Harvest index

Treatment $Mg_{0.5}$ gave the maximum value for this yield parameter. Its effect was followed by that of $Mg_{1.0}$. Treatment $Mg_{0.5}$ increased harvest index by 2.8% over Mg_0.

Cultivar Shubhra gave the maximum value. However, it was equalled by Parvati. Cultivar Shubhra gave 3.2% higher value than Shekhar which gave the lowest value.

Table 76. Effect of foliar application of Mg on 1000-seed weight and seed yield per plant of linseed cultivars at harvest (Mean of four replicates)

Treatments (T) (kg/ha)	Cultivars (Cv)			Mean
	Parvati	Shekhar	Shubhra	
		1000-seed weight (g)		
Mg_0	7.76	7.83	8.03	7.87
$Mg_{0.5}$	8.12	8.17	8.26	8.18
$Mg_{1.0}$	8.04	8.19	8.19	8.14
$Mg_{1.5}$	7.88	7.97	8.11	7.99
Mean	7.95	8.04	8.15	
CD at 5%	T= NS	Cv = NS	T x Cv = NS	
		Seed yield per plant (g)		
Mg_0	2.94	3.30	3.43	3.22
$Mg_{0.5}$	3.60	4.09	4.36	4.02
$Mg_{1.0}$	3.52	4.03	4.20	3.92
$Mg_{1.5}$	3.10	3.51	3.67	3.43
Mean	3.29	3.73	3.92	
CD at 5%	T = 0.07	Cv = 0.06	T x Cv = 0.12	

NB: A uniform pre-sowing seed and foliar treatment of 10^{-6}M GA_3 as well as a basal dose of $N_{60}P_{20}K_{30}$ was applied.

NS= Non-significant

Table 77. Effect of foliar application of Mg on biological yield per plant and harvest index of linseed cultivars at harvest (Mean of four replicates)

Treatments (T) (kg/ha)	Cultivars (Cv)			Mean
	Parvati	Shekhar	Shubhra	
		Biological yield per plant (g)		
Mg_0	11.17	12.85	12.96	12.33
$Mg_{0.5}$	13.29	15.59	15.95	14.94
$Mg_{1.0}$	13.21	15.42	15.72	14.78
$Mg_{1.5}$	11.68	13.57	13.75	13.00
Mean	12.34	14.36	14.60	
CD at 5%	T= 0.79	Cv = 0.68	T x Cv = 1.36	
		Harvest index (%)		
Mg_0	26.33	25.69	26.47	26.16
$Mg_{0.5}$	27.09	26.24	27.34	26.89
$Mg_{1.0}$	26.65	26.13	26.71	26.50
$Mg_{1.5}$	26.55	25.86	26.70	26.37
Mean	26.66	25.98	26.81	
CD at 5%	T =0.14	Cv =0.12	T x Cv =0.24	

NB: A uniform pre-sowing seed and foliar treatment of 10^{-6}M GA_3 as well as a basal dose of $N_{60}P_{20}K_{30}$ was applied.

Among interactions, $Mg_{0.5}$ x Shubhra gave the maximum value. Its effect was followed by that of $Mg_{0.5}$ x Parvati. Interaction $Mg_{0.5}$ x Shubhra gave 6.4% higher value than Mg_0 x Shekhar which gave the lowest value (Table 77).

4.4.3.7 Oil content

The effect of treatments on oil content was not significant.

Of cultivars, Shubhra gave the maximum value. However, it was equalled by Shekhar. Shubhra gave 7.4% higher oil percentage than Pavati which gave the lowest value.

The effect of interactions was also not significant on oil content (Table 78).

4.4.3.8 Oil yield per plant

Spray treatment $Mg_{0.5}$ gave the maximum value for this yield parameter. However, its effect was equalled by that of $Mg_{1.0}$. Spray treatment $Mg_{0.5}$ gave 27.4% higher value than Mg_0.

Of cultivars, Shubhra proved best. It was followed by Shekhar. Cultivar Shubhra gave 27.6% higher oil yield than Parvati which gave the lowest value.

Interaction $Mg_{0.5}$ x Shubhra gave the maximum value. However its effect was equalled by that of $Mg_{1.0}$ x Shubhra. Interaction $Mg_{0.5}$ x Shubhra enhanced oil yield by 63.0% over Mg_0 x Parvati which gave the least value (Table 78).

4.4.3.9 Iodine value

The effect of treatments and their interactions with cultivars was not significant on iodine value of the oil. However, cultivar differences were significant (Table 79).

Cultivar Shekhar gave the highest iodine value. It was equalled by Shubhra. Cultivar Shekhar gave 5.6% higher iodine value than Parvati which gave the lowest value (Table 79).

4.4.3.10 Fibre yield per plant

Spray treatment $Mg_{0.5}$ gave the maximum value. However, its effect was at par with that of $Mg_{1.0}$. Treatment $Mg_{0.5}$ improved fibre yield by 21.6% over Mg_0.

Table 78. Effect of foliar application of Mg on oil content and oil yield per plant of linseed cultivars at harvest (Mean of four replicates)

Treatments (T) (kg/ha)	Cultivars (Cv)			Mean
	Parvati	Shekhar	Shubhra	
		Oil content (%)		
Mg_0	36.61	39.21	39.38	38.40
$Mg_{0.5}$	37.42	39.61	40.27	39.10
$Mg_{1.0}$	37.59	39.73	40.16	39.16
$Mg_{1.5}$	37.04	39.43	39.82	38.76
Mean	37.17	39.50	39.91	
CD at 5%	T= NS	Cv = 1.86	T x Cv = NS	
		Oil yield per plant (g)		
Mg_0	1.08	1.29	1.35	1.24
$Mg_{0.5}$	1.35	1.62	1.76	1.58
$Mg_{1.0}$	1.32	1.60	1.69	1.54
$Mg_{1.5}$	1.15	1.38	1.46	1.33
Mean	1.23	1.47	1.57	
CD at 5%	T = 0.05	Cv = 0.05	T x Cv = 0.09	

NB: A uniform pre-sowing seed and foliar treatment of 10^{-6}M GA_3 as well as a basal dose of $N_{60}P_{20}K_{30}$ was applied.

NS = Non-significant

Table 79. Effect of foliar application of Mg on iodine value of linseed cultivars at harvest (Mean of four replicates)

Treatments (T) (kg/ha)	Cultivars (Cv)			Mean
	Parvati	Shekhar	Shubhra	
		Iodine value		
Mg_0	183.28	190.74	182.66	185.56
$Mg_{0.5}$	188.27	201.18	191.51	193.65
$Mg_{1.0}$	188.35	197.51	187.38	191.08
$Mg_{1.5}$	183.28	195.74	194.42	191.15
Mean	185.80	196.29	188.99	
CD at 5%	T= NS	Cv = 9.58	T x Cv = NS	

NB: A uniform pre-sowing seed and foliar treatment of $10^{-6}M\ GA_3$ as well as a basal dose of $N_{60}P_{20}K_{30}$ was applied.

NS = Non-significant

Cultivar Shubhra gave the maximum value. It was equalled by Shekhar. Cultivar Shubhra gave 11.2% higher value than Parvati which gave the lowest value.

Of interactions, $Mg_{0.5}$ x Shubhra gave the maximum value. However, its effect was at par with that of $Mg_{0.5}$ x Shekhar and $Mg_{1.0}$ x Shubhra. Interaction, $Mg_{0.5}$ x Shubhra gave 35.6% higher value than Mg_0 x Parvati which gave the lowest value (Table 80).

4.4.3.11 Lodging

Spray treatment Mg_0 gave the maximum value, however its effect was at par with that of $Mg_{0.5}$. Treatment Mg_0 gave 10.4% higher value than $Mg_{1.5}$ which exhibited the least value.

Of cultivars, Parvati showed the maximum value for this parameter. It was followed by Shekhar and Shubhra. Cultivar Parvati increased lodging by 11.7% over Shubhra which gave the minimum value.

Of interactions, Mg_0 x Parvati gave the maximum value. However, its effect was at par with that of $Mg_{0.5}$ x Shekhar, $Mg_{0.5}$ x Parvati, $Mg_{1.5}$ x Parvati and Mg_0 x Shubhra. Interaction Mg_0 x Parvati gave 32.3% higher value than $Mg_{1.5}$ x Shubhra which gave the minimum value (Table 81).

4.5 Experiment 5

This factorial randomized pot experiment was planned with the aim whether the combination of the best doses of spray Ca and Mg emanated from Experiments 3 and 4 could further enhance the performance of the three better performing cultivars of linseed (Parvati, Shekhar and Shubhra) grown with the uniform best pre-sowing seed and foliar treatment of GA_3 (10^{-6}M) and nutrient dose $N_{60}P_{20}K_{30}$ obtained from the data of Experiments 1 and 2. The parameters studied were kept the same as in Experiment 1, with leaf Ca and Mg content also being estimated. The results (Tables 82-101) are summarized below.

4.5.1 Growth characteristics

The effect of spray treatments of Ca and Mg and their interactions with cultivars on all growth characteristics, as also cultivar differences, were significant at both sampling stages, except leaf area index on which effect of spray

Table 80. Effect of foliar application of Mg on fibre yield per plant of linseed cultivars at harvest (Mean of four replicates)

Treatments (T) (kg/ha)	Cultivars (Cv)			Mean
	Parvati	Shekhar	Shubhra	
	Fibre yield per plant (g)			
Mg_0	1.342	1.476	1.478	1.432
$Mg_{0.5}$	1.592	1.811	1.820	1.741
$Mg_{1.0}$	1.581	1.780	1.796	1.719
$Mg_{1.5}$	1.512	1.611	1.608	1.577
Mean	1.507	1.670	1.676	
CD at 5%	T= 0.023	Cv = 0.020	T x Cv = 0.039	

NB: A uniform pre-sowing seed and foliar treatment of 10^{-6}M GA_3 as well as a basal dose of $N_{60}P_{20}K_{30}$ was applied.

Table 81. Effect of foliar application of Mg on lodging of linseed cultivars at harvest (Mean of four replicates)

Treatments (T) (kg/ha)	Cultivars (Cv)			Mean
	Parvati	Shekhar	Shubhra	
		Lodging (%)		
Mg_0	39.7	35.0	36.3	37.0
$Mg_{0.5}$	37.3	37.7	34.0	36.3
$Mg_{1.0}$	35.0	34.3	32.7	34.0
$Mg_{1.5}$	36.7	33.7	30.0	33.5
Mean	37.2	35.2	33.3	
CD at 5%	T= 2.15	Cv = 1.86	T x Cv = 3.72	

NB: A uniform pre-sowing seed and foliar treatment of 10^{-6}M GA_3 as well as a basal dose of $N_{60}P_{20}K_{30}$ was applied.

treatment x cultivar interactions as well as cultivar differences for this parameter at 75 DAS (Tables 82-86).

4.5.1.1 Height per plant

Spray treatment $Ca_2Mg_{0.5}$ proved best at both sampling stages. Its effect was followed at 60 DAS but equalled at 75 DAS by that of Ca_2Mg_0. Treatment $Ca_2Mg_{0.5}$ gave 23.0 and 12.0 % higher value at 60 and 75 DAS respectively than Ca_0Mg_0.

Cultivar Shubhra performed best at 60 DAS but Shekhar at 75 DAS. Cultivar Shubhra was followed by Shekhar at 60 DAS and the reverse was true at 75 DAS. Cultivar Shubhra gave 13.8 and 10.6% higher value at 60 and 75 DAS respectively than Parvati which gave the minimum value.

Among interactions, $Ca_2Mg_{0.5}$ x Shubhra and $Ca_2Mg_{0.5}$ x Shekhar gave the maximum value at 60 and 75 DAS respectively. The effect of $Ca_2Mg_{0.5}$ x Shubhra was equalled by that of Ca_2Mg_0 x Shubhra at 60 DAS and also by that of $Ca_2Mg_{0.5}$ x Shekhar and Ca_2Mg_0 x Shekhar at 75 DAS. Interaction $Ca_2Mg_{0.5}$ x Shubhra gave 41.1 and 26.1% higher value at 60 and 75 DAS respectively than Ca_0Mg_0 x Parvati which gave the lowest value (Table 82).

4.5.1.2 Leaf area per plant

Of spray treatments, $Ca_2Mg_{0.5}$ and Ca_2Mg_0 gave the maximum value at 60 and 75 DAS respectively. The effect of $Ca_2Mg_{0.5}$ was followed at 60 DAS but equalled at 75 DAS by that of Ca_2Mg_0. Treatment $Ca_2Mg_{0.5}$ gave 37.7 and 19.4% higher value at 60 and 75 DAS respectively than Ca_0Mg_0.

Cultivar Shubhra gave the maximum value at each sampling stage, with Shekhar following it. Shubhra gave 14.2 and 10.5% higher value at 60 and 75 DAS respectively than Parvati which gave the lowest value.

Interactions $Ca_2Mg_{0.5}$ x Shubhra and Ca_2Mg_0 x Shubhra gave the maximum value at 60 and 75 DAS respectively. The effect of $Ca_2Mg_{0.5}$ x Shubhra was followed at 60 DAS but equalled at 75 DAS by that of Ca_2Mg_0 x Shubhra. Interaction $Ca_2Mg_{0.5}$ x Shubhra increased leaf area per plant by 57.5 and 32.6% at 60 and 75 DAS respectively over Ca_0Mg_0 x Parvati which gave the lowest value (Table 83).

Table 82. Effect of foliar application of Ca and Mg on height per plant (cm) of linseed cultivars at two stages of growth (Mean of four replicates)

Treatments (T) (kg/ha)	Cultivars (Cv)			Mean
	Parvati	Shekhar	Shubhra	
		60 DAS		
Ca_0Mg_0	51.6	54.4	59.5	55.2
Ca_2Mg_0	63.7	59.2	68.3	63.7
$Ca_0Mg_{0.5}$	53.5	58.9	63.6.	58.7
$Ca_2Mg_{0.5}$	63.4	67.4	72.8	67.9
Mean	58.1	60.0	66.1	
CD at 5%	T= 3.00	Cv = 2.60	T x Cv = 5.19	
		75 DAS		
Ca_0Mg_0	59.3	69.5	65.7	64.8
Ca_2Mg_0	68.0	74.2	73.5	71.9
$Ca_0Mg_{0.5}$	62.5	71.7	68.6	67.6
$Ca_2Mg_{0.5}$	65.6	77.4	74.8	72.6
Mean	63.9	73.2	70.7	
CD at 5%	T = 2.34	Cv = 2.03	T x Cv = 4.06	

NB: A uniform pre-sowing seed and foliar treatment of 10^{-6}M GA_3 as well as a basal dose of $N_{60}P_{20}K_{30}$ was applied.

Table 83. Effect of foliar application of Ca and Mg on leaf area per plant (cm^2) of linseed cultivars at two stages of growth (Mean of four replicates)

Treatments (T) (kg/ha)	Cultivars (Cv)			Mean
	Parvati	Shekhar	Shubhra	
		60 DAS		
Ca_0Mg_0	163.52	170.27	194.36	176.05
Ca_2Mg_0	220.15	237.29	248.00	235.15
$Ca_0Mg_{0.5}$	188.43	196.30	217.51	200.75
$Ca_2Mg_{0.5}$	231.00	238.53	257.62	242.38
Mean	200.78	210.60	229.37	
CD at 5%	T= 5.50	Cv = 4.77	T x Cv = 9.53	
		75 DAS		
Ca_0Mg_0	427.29	456.38	470.50	451.39
Ca_2Mg_0	517.71	539.62	569.38	542.24
$Ca_0Mg_{0.5}$	469.41	490.17	518.00	492.53
$Ca_2Mg_{0.5}$	508.33	541.50	566.47	538.77
Mean	480.69	506.92	530.97	
CD at 5%	T = 4.58	Cv = 4.20	T x Cv = 8.40	

NB: A uniform pre-sowing seed and foliar treatment of 10^{-6}M GA_3 as well as a basal dose of $N_{60}P_{20}K_{30}$ was applied.

4.5.1.3 Leaf area index

Spray treatments $Ca_2Mg_{0.5}$ and Ca_2Mg_0 gave the maximum value at 60 and 75 DAS respectively. The effect of $Ca_2Mg_{0.5}$ was equalled by that of Ca_2Mg_0 at 60 DAS and also by that of $Ca_0Mg_{0.5}$ at 75 DAS. Spray of $Ca_2Mg_{0.5}$ enhanced leaf area index by 37.6 and 19.4% at 60 and 75 DAS respectively over Ca_0Mg_0.

Cultivar Shubhra performed best at 60 DAS, with Shekhar following it. Cultivar shubhra gave 14.2% higher value at this stage than Parvati which gave the lowest value. However, cultivar differences were not significant at 75 DAS.

Among interactions, $Ca_2Mg_{0.5}$ x Shubhra gave the maximum value at 60 DAS, with its effect being at par with that of Ca_2Mg_0 x Shubhra. Interaction $Ca_2Mg_{0.5}$ x Shubhra gave 57.7% higher value than Ca_0Mg_0 x Parvati which gave the lowest value at 60 DAS. However, interaction effect was not significant at 75 DAS (Table 84).

4.5.1.4 Fresh weight per plant

Spray treatment $Ca_2Mg_{0.5}$ gave the maximum value at both stages. Its effect was followed at 60 DAS but equalled at 75 DAS by that of Ca_2Mg_0. Spray treatment $Ca_2Mg_{0.5}$ gave 64.5 and 37.2% higher value at 60 and 75 DAS respectively than Ca_0Mg_0.

Of cultivars, Shubhra proved best at both sampling stages. It was followed by Parvatri (also Shekhar) at each stage. Cultivar Shubhra gave 22.0 and 15.0% higher value at 60 and 75 DAS respectively than Parvati which gave the minimum value.

Among interactions, $Ca_2Mg_{0.5}$ x Shubhra gave the maximum value at each stage. However, its effect was equalled by that of Ca_2Mg_0 x Shubhra at both stages. Treatment $Ca_2Mg_{0.5}$ x Shubhra gave 104.1 and 58.8% higher value at 60 and 75 DAS respectively than Ca_0Mg_0 x Parvati which gave the lowest value (Table 85).

4.5.1.5 Dry weight per plant

Spray treatment $Ca_2Mg_{0.5}$ gave the maximum value at each stage. However, its effect was followed by that of Ca_2Mg_0 at both stages. Treatment $Ca_2Mg_{0.5}$ gave 38.2 and 20.6% higher value at 60 and 75 DAS respectively than Ca_0Mg_0.

Table 84. Effect of foliar application of Ca and Mg on leaf area index of linseed cultivars at two stages of growth (Mean of four replicates)

Treatments (T) (kg/ha)	Cultivars (Cv)			Mean
	Parvati	Shekhar	Shubhra	
		60 DAS		
Ca_0Mg_0	3.33	3.47	3.96	3.59
Ca_2Mg_0	4.48	4.83	5.05	4.79
$Ca_0Mg_{0.5}$	3.84	4.00	4.43	4.09
$Ca_2Mg_{0.5}$	4.70	4.86	5.25	4.94
Mean	4.09	4.29	4.67	
CD at 5%	T= 0.20	Cv = 0.18	T x Cv = 0.35	
		75 DAS		
Ca_0Mg_0	8.70	9.29	9.58	9.19
Ca_2Mg_0	10.54	10.99	11.59	11.04
$Ca_0Mg_{0.5}$	9.56	9.98	10.55	10.03
$Ca_2Mg_{0.5}$	10.35	11.03	11.54	10.97
Mean	9.79	10.32	10.82	
CD at 5%	T = 0.16	Cv = 0.14	T x Cv = 0.27	

NB: A uniform pre-sowing seed and foliar treatment of 10^{-6}M GA_3 as well as a basal dose of $N_{60}P_{20}K_{30}$ was applied.

Table 85. Effect of foliar application of Ca and Mg on fresh weight per plant (g) of linseed cultivars at two stages of growth (Mean of four replicates)

Treatments (T) (kg/ha)	Cultivars (Cv)			Mean
	Parvati	Shekhar	Shubhra	
		60 DAS		
Ca_0Mg_0	15.27	14.51	18.60	16.13
Ca_2Mg_0	22.11	20.49	27.32	23.31
$Ca_0Mg_{0.5}$	19.35	17.83	22.18	19.79
$Ca_2Mg_{0.5}$	24.61	23.84	31.17	26.54
Mean	20.34	19.17	24.82	
CD at 5%	T= 2.28	Cv = 1.98	T x Cv = 3.95	
		75 DAS		
Ca_0Mg_0	25.10	24.38	27.00	25.49
Ca_2Mg_0	32.74	30.19	37.65	33.53
$Ca_0Mg_{0.5}$	29.41	28.50	33.25	30.39
$Ca_2Mg_{0.5}$	32.53	32.54	39.86	34.98
Mean	29.95	28.90	34.44	
CD at 5%	T = 1.83	Cv = 1.59	T x Cv = 3.17	

NB: A uniform pre-sowing seed and foliar treatment of 10^{-6}M GA_3 as well as a basal dose of $N_{60}P_{20}K_{30}$ was applied.

Of cultivars, Shubhra gave the maximum value at both stages, with Shekhar following it. Shubhra gave 28.8 and 19.3% higher value at 60 and 75 DAS respectively than Parvati which gave the minimum value.

Among interactions, $Ca_2Mg_{0.5}$ x Shubhra gave the maximum value at both stages. Its effect was followed at 60 DAS but equalled at 75 DAS by that of Ca_2Mg_0 x Shubhra. Interaction $Ca_2Mg_{0.5}$ x Shubhra gave 79.6 and 40.1% higher value at 60 and 75 DAS respectively than Ca_0Mg_0 x Parvati which gave the lowest value (Table 86).

4.5.2 Physiological and biochemical parameters

The effect of treatments and their interactions with cultivars on all physiological and biochemical parameters, as also cultivar differences, were significant at both stages, except leaf N content at both stages and leaf P and K content at 75 DAS (Tables 87-94).

4.5.2.1 Net photosynthetic rate

Spray treatments $Ca_2Mg_{0.5}$ and $Ca_0Mg_{0.5}$, being at par, gave higher values than other treatments at both stages. Spray treatment $Ca_2Mg_{0.5}$ gave 20.7 and 19.1% higher value at 60 and 75 DAS respectively than Ca_0Mg_0.

Cultivar Shubhra gave the maximum value at each stage. It was followed at 60 DAS but equalled at 75 DAS by Shekhar. Cultivar Shubhra gave 4.7 and 5.8% higher value at 60 and 75 DAS respectively than Parvati which gave the lowest value.

Among interactions, $Ca_2Mg_{0.5}$ x Shubhra and $Ca_0Mg_{0.5}$ x Shubhra gave the maximum value at 60 and 75 DAS respectively. However, the effect of the former was equalled by that of the latter at 60 DAS and also by that of $Ca_2Mg_{0.5}$ x Shekhar and $Ca_0Mg_{0.5}$ x Shekhar at 75 DAS. Interaction $Ca_2Mg_{0.5}$ x Shubhra gave 27.1 and 25.1% higher value at 60 and 75 DAS respectively than Ca_0Mg_0 x Parvati which gave the minimum value (Table 87).

4.5.2.2 Carbonic anhydrase activity

Spray treatment $Ca_2Mg_{0.5}$ gave the maximum value at both sampling stages, with its effect being at par with that of $Ca_0Mg_{0.5}$. Spray treatment $Ca_2Mg_{0.5}$ enhanced CA activity by 21.8 and 15.3% at 60 and 75 DAS respectively over Ca_0Mg_0.

Table 86. Effect of foliar application of Ca and Mg on dry weight per plant (g) of linseed cultivars at two stages of growth (Mean of four replicates)

Treatments (T) (kg/ha)	Cultivars (Cv)			Mean
	Parvati	Shekhar	Shubhra	
		60 DAS		
Ca_0Mg_0	3.62	4.13	4.96	4.24
Ca_2Mg_0	4.90	5.71	6.19	5.60
$Ca_0Mg_{0.5}$	4.18	4.60	5.44	4.74
$Ca_2Mg_{0.5}$	5.23	5.84	6.50	5.86
Mean	4.48	5.07	5.77	
CD at 5%	T= 0.13	Cv = 0.12	T x Cv = 0.23	
		75 DAS		
Ca_0Mg_0	6.29	6.58	7.62	6.83
Ca_2Mg_0	7.06	7.49	8.74	7.76
$Ca_0Mg_{0.5}$	6.71	7.32	7.96	7.33
$Ca_2Mg_{0.5}$	7.69	8.21	8.81	8.24
Mean	9.94	7.40	8.28	
CD at 5%	T = 0.20	Cv = 0.17	T x Cv = 0.34	

NB: A uniform pre-sowing seed and foliar treatment of 10^{-6}M GA_3 as well as a basal dose of $N_{60}P_{20}K_{30}$ was applied.

Table 87. Effect of foliar application of Ca and Mg on net photosynthetic rate [μmol $(CO_2)/m^2/s$] of linseed cultivars at two stages of growth (Mean of four replicates)

Treatments (T) (kg/ha)	Cultivars (Cv)			Mean
	Parvati	Shekhar	Shubhra	
		60 DAS		
Ca_0Mg_0	18.51	18.69	18.64	18.61
Ca_2Mg_0	19.25	19.72	20.17	19.71
$Ca_0Mg_{0.5}$	22.19	22.15	23.49	22.61
$Ca_2Mg_{0.5}$	22.06	21.83	23.52	22.47
Mean	20.50	20.60	21.46	
CD at 5%	T= 0.72	Cv = 0.63	T x Cv = 1.25	
		75 DAS		
Ca_0Mg_0	20.24	20.77	21.59	20.87
Ca_2Mg_0	21.76	22.38	23.07	22.40
$Ca_0Mg_{0.5}$	24.31	25.17	25.66	25.05
$Ca_2Mg_{0.5}$	24.06	25.20	25.32	24.86
Mean	22.59	23.38	23.91	
CD at 5%	T = 0.69	Cv = 0.60	T x Cv = 1.19	

NB: A uniform pre-sowing seed and foliar treatment of 10^{-6}M GA_3 as well as a basal dose of $N_{60}P_{20}K_{30}$ was applied.

Of cultivars, Shubhra proved best at both stages, with Shekhar following it. Shubhra gave 8.4 and 6.2% higher value at 60 and 75 DAS respectively than Parvati which gave the lowest value.

Interaction $Ca_2Mg_{0.5}$ x Shubhra gave the maximum value at each stage, with its effect being at par with that of $Ca_0Mg_{0.5}$ x Shubhra. Interaction $Ca_2Mg_{0.5}$ x Shubhra improved CA activity by 31.0 and 22.3% at 60 and 75 DAS respectively over Ca_0Mg_0 x Parvati which gave the lowest value (Table 88).

4.5.2.3 Leaf chlorophyll content

Spray treatment $Ca_0Mg_{0.5}$ gave the maximum value for this parameter at both stages. However, its effect was equalled by that of $Ca_2Mg_{0.5}$ at each stage. Spray treatment $Ca_2Mg_{0.5}$ gave 29.1 and 25.7% higher value at 60 and 75 DAS respectively than Ca_0Mg_0.

Cultivar Shubhra gave the maximum value at each stage, with Shekhar following it. Cultivar Shubhra gave 3.5 and 3.3% higher value at 60 and 75 DAS respectively than Parvati which gave the lowest value.

Among interactions, $Ca_0Mg_{0.5}$ x Shubhra gave the maximum value at both stages. However, its effect was equalled by that of $Ca_2Mg_{0.5}$ x Shubhra and $Ca_0Mg_{0.5}$ x Shekhar at 60 DAS and also by that of $Ca_2Mg_{0.5}$ x Shekhar at 75 DAS. Interaction $Ca_2Mg_{0.5}$ x Shubhra gave 33.2 and 28.8% higher value at 60 and 75 DAS respectively than Ca_0Mg_0 x Parvati which gave the lowest value (Table 89).

4.5.2.4 Leaf N content

The effect of treatments and their interactions on leaf N content, as also cultivar differences, were not significant at both stages (Table 90).

4.5.2.5 Leaf P content

At 60 DAS, spray treatment $Ca_2Mg_{0.5}$ gave the maximum value, however its effect was equalled by that of Ca_2Mg_0. Treatment $Ca_2Mg_{0.5}$ gave 5.4% higher value at this stage than Ca_0Mg_0. However, the effect of treatments on this parameter was not significant at 75 DAS.

At 60 DAS, cultivar Shubhra performed best, with Shekhar (also Parvati) following it. Cultivar Shubhra gave 5.0% higher value at 60 DAS than Parvati which gave the lowest value. However at 75 DAS, cultivars did not vary.

Table 88. Effect of foliar application of Ca and Mg on carbonic anhydrase activity [µmol (CO_2)/kg (f.m.)/s] of linseed cultivars at two stages of growth (Mean of four replicates)

Treatments (T) (kg/ha)	Cultivars (Cv)			Mean
	Parvati	Shekhar	Shubhra	
		60 DAS		
Ca_0Mg_0	372.61	381.27	397.53	383.80
Ca_2Mg_0	409.17	421.43	446.68	425.76
$Ca_0Mg_{0.5}$	431.00	449.19	471.35	450.51
$Ca_2Mg_{0.5}$	451.27	463.51	488.09	467.62
Mean	416.01	428.85	450.91	
CD at 5%	T= 11.24	Cv = 9.74	T x Cv = 19.47	
		75 DAS		
Ca_0Mg_0	452.29	463.94	472.19	462.81
Ca_2Mg_0	491.68	507.89	519.83	506.47
$Ca_0Mg_{0.5}$	503.47	521.33	541.29	522.03
$Ca_2Mg_{0.5}$	517.16	531.07	553.17	533.80
Mean	491.15	506.06	521.62	
CD at 5%	T = 7.15	Cv = 6.20	T x Cv = 12.39	

NB: A uniform pre-sowing seed and foliar treatment of 10^{-6}M GA_3 as well as a basal dose of $N_{60}P_{20}K_{30}$ was applied.

Table 89. Effect of foliar application of Ca and Mg on leaf chlorophyll content (mg/g f.m.) of linseed cultivars at two stages of growth (Mean of four replicates)

Treatments (T) (kg/ha)	Cultivars (Cv)			Mean
	Parvati	Shekhar	Shubhra	
		60 DAS		
Ca_0Mg_0	1.317	1.311	1.336	1.321
Ca_2Mg_0	1.450	1.461	1.493	1.468
$Ca_0Mg_{0.5}$	1.683	1.704	1.762	1.716
$Ca_2Mg_{0.5}$	1.679	1.686	1.754	1.706
Mean	1.532	1.541	1.586	
CD at 5%	T= 0.038	Cv = 0.033	T x Cv = 0.065	
		75 DAS		
Ca_0Mg_0	1.462	1.457	1.486	1.468
Ca_2Mg_0	1.640	1.632	1.662	1.645
$Ca_0Mg_{0.5}$	1.802	1.856	1.890	1.849
$Ca_2Mg_{0.5}$	1.793	1.858	1.883	1.845
Mean	1.674	1.701	1.730	
CD at 5%	T = 0.021	Cv = 0.018	T x Cv = 0.036	

NB: A uniform pre-sowing seed and foliar treatment of 10^{-6}M GA_3 as well as a basal dose of $N_{60}P_{20}K_{30}$ was applied.

Table 90. Effect of foliar application of Ca and Mg on leaf N content (%) of linseed cultivars at two stages of growth (Mean of four replicates)

Treatments (T) (kg/ha)	Cultivars (Cv)			Mean
	Parvati	Shekhar	Shubhra	
		60 DAS		
Ca_0Mg_0	2.44	2.53	2.60	2.52
Ca_2Mg_0	2.61	2.75	2.86	2.74
$Ca_0Mg_{0.5}$	2.31	2.42	2.51	2.41
$Ca_2Mg_{0.5}$	2.76	2.98	3.14	2.96
Mean	2.53	2.67	2.78	
CD at 5%	T= NS	Cv = NS	T x Cv = NS	
		75 DAS		
Ca_0Mg_0	2.86	2.88	3.06	2.93
Ca_2Mg_0	2.94	2.93	3.17	3.01
$Ca_0Mg_{0.5}$	2.72	2.76	2.97	2.82
$Ca_2Mg_{0.5}$	3.24	3.20	3.32	3.25
Mean	2.94	2.94	3.13	
CD at 5%	T = NS	Cv = NS	T x Cv = NS	

NB: A uniform pre-sowing seed and foliar treatment of 10^{-6}M GA_3 as well as a basal dose of $N_{60}P_{20}K_{30}$ was applied.

NS = Non-significant

Of interactions, $Ca_2Mg_{0.5}$ x Shubhra gave the maximum value at 60 DAS. Its effect was equalled by that of Ca_2Mg_0 x Shubhra (and Parvati), $Ca_2Mg_{0.5}$ x Shekhar (also Parvati) and Ca_0Mg_0 x Shubhra at this stage. Interaction $Ca_2Mg_{0.5}$ x Shubhra gave 11.3% higher value at 60 DAS than Ca_0Mg_0 x Parvati which gave the lowest value. However at 75 DAS, a non-significant effect was noticed in respect of interactions (Table 91).

4.5.2.6 Leaf K content

At 60 DAS, spray treatment $Ca_2Mg_{0.5}$ gave the maximum value, with its effect being at par with that of Ca_2Mg_0. Treatment $Ca_2Mg_{0.5}$ gave 6.4% higher value at 60 DAS than Ca_0Mg_0. However, treatment effect was not significant at 75 DAS.

Of cultivars, Shubhra exhibited the maximum leaf K content at 60 DAS. It was followed by Parvati and Shekhar at this stage. Cultivar Shubhra gave 3.6% higher value at 60 DAS than Parvati which gave the minimum value. However, cultivars showed parity in respect of this parameter at 75 DAS.

Interaction $Ca_2Mg_{0.5}$ x Shubhra gave the maximum value at 60 DAS. However, its effect was at par with that of Ca_2Mg_0 x Shubhra and $Ca_2Mg_{0.5}$ x Parvati (also Shekhar) at this stage. Interaction $Ca_2Mg_{0.5}$ x Shubhra gave 16.2% higher value at 60 DAS than $Ca_0Mg_{0.5}$ x Shekhar which gave the lowest value. However, a non-significant effect of interactions was found on this parameter at 75 DAS (Table 92).

4.5.2.7 Leaf Ca content

Spray treatment Ca_2Mg_0 gave the maximum value for leaf Ca content at both stages. Its effect was followed by that of $Ca_2Mg_{0.5}$ at each stage. Treatment Ca_2Mg_0 increased leaf Ca content by 48.7 and 40.4% at 60 and 75 DAS respectively over Ca_0Mg_0.

Cultivar Shubhra gave the maximum value at both sampling stages. However, it was at par with Shekhar at 60 DAS but followed by the same (Shekhar) and Parvati at 75 DAS. Cultivar Shubhra gave 22.0 and 18.4% higher value at 60 and 75 DAS respectively than Parvati which gave the lowest value.

Table 91. Effect of foliar application of Ca and Mg on leaf P content (%) of linseed cultivars at two stages of growth (Mean of four replicates)

Treatments (T) (kg/ha)	Cultivars (Cv)			Mean
	Parvati	Shekhar	Shubhra	
		60 DAS		
Ca_0Mg_0	0.256	0.259	0.268	0.261
Ca_2Mg_0	0.266	0.262	0.279	0.269
$Ca_0Mg_{0.5}$	0.249	0.251	0.260	0.253
$Ca_2Mg_{0.5}$	0.268	0.273	0.285	0.275
Mean	0.260	0.261	0.273	
CD at 5%	T= 0.012	Cv = 0.011	T x Cv = 0.021	
		75 DAS		
Ca_0Mg_0	0.270	0.272	0.281	0.274
Ca_2Mg_0	0.275	0.279	0.288	0.281
$Ca_0Mg_{0.5}$	0.265	0.268	0.279	0.271
$Ca_2Mg_{0.5}$	0.281	0.286	0.311	0.293
Mean	0.273	0.276	0.290	
CD at 5%	T = NS	Cv = NS	T x Cv = NS	

NB: A uniform pre-sowing seed and foliar treatment of 10^{-6}M GA_3 as well as a basal dose of $N_{60}P_{20}K_{30}$ was applied.

NS = Non-significant

Table 92. Effect of foliar application of Ca and Mg on leaf K content (%) of linseed cultivars at two stages of growth (Mean of four replicates)

Treatments (T) (kg/ha)	Cultivars (Cv)			Mean
	Parvati	Shekhar	Shubhra	
		60 DAS		
Ca_0Mg_0	2.49	2.42	2.57	2.49
Ca_2Mg_0	2.59	2.51	2.69	2.60
$Ca_0Mg_{0.5}$	2.41	2.34	2.49	2.41
$Ca_2Mg_{0.5}$	2.63	2.60	2.72	2.65
Mean	2.53	2.47	2.62	
CD at 5%	T= 0.07	Cv = 0.06	T x Cv = 0.12	
		75 DAS		
Ca_0Mg_0	2.62	2.60	2.72	2.65
Ca_2Mg_0	2.68	2.71	2.80	2.73
$Ca_0Mg_{0.5}$	2.52	2.48	2.61	2.54
$Ca_2Mg_{0.5}$	2.81	2.74	2.86	2.80
Mean	2.66	2.63	2.75	
CD at 5%	T = NS	Cv = NS	T x Cv = NS	

NB: A uniform pre-sowing seed and foliar treatment of 10^{-6}M GA_3 as well as a basal dose of $N_{60}P_{20}K_{30}$ was applied.

NS = Non-significant

Among interactions, Ca_2Mg_0 x Shubhra gave the maximum value at both stages. Its effect was at par with that of Ca_2Mg_0 x Shekhar and $Ca_2Mg_{0.5}$ x Shubhra at 60 DAS but followed by that of these two interactions and Ca_2Mg_0 x Parvati at 75 DAS. Interaction Ca_2Mg_0 x Shubhra gave 75.0 and 69.8% higher value at 60 and 75 DAS respectively than Ca_0Mg_0 x Parvati which gave the lowest value (Table 93).

4.5.2.8 Leaf Mg content

Spray treatment $Ca_0Mg_{0.5}$ gave the maximum value at both sampling stages. Its effect was equalled at 60 DAS but followed at 75 DAS by that of $Ca_2Mg_{0.5}$ and Ca_0Mg_0. Spray treatment $Ca_0Mg_{0.5}$ gave 30.8 and 28.6% higher value at 60 and 75 DAS respectively than Ca_0Mg_0.

Of cultivars, Shubhra gave the maximum value at both stages, with Shekhar following it. Shubhra gave 18.5 and 20.6% higher leaf Mg content at 60 and 75 DAS respectively than Parvati which gave the lowest value.

Interaction $Ca_0Mg_{0.5}$ x Shubhra gave the maximum value at both stages. Its effect was equalled by that of $Ca_2Mg_{0.5}$ x Shubhra, $Ca_0Mg_{0.5}$ x Shekhar and $Ca_0Mg_{0.5}$ x Parvati at both stages and also by that of $Ca_2Mg_{0.5}$ x Shekhar at 60 DAS. Interaction $Ca_0Mg_{0.5}$ x Shubhra gave 60.9 and 54.8% higher value at 60 and 75 DAS respectively than Ca_0Mg_0 x Parvati which gave the lowest value (Table 94).

4.5.3 Yield and quality characteristics

The effect of treatments and their interactions with cultivars on capsules per plant, 1000-seed weight, seed yield per plant, harvest index, oil yield per plant and fibre yield, as also cultivar differences were significant. However, the effect of treatments and their interactions with cultivars on seeds per capsule, oil content and iodine value was not significant. Also, cultivars did not vary in respect of biological yield per plant and iodine value (Tables 95-101).

4.5.3.1 Capsules per plant

Spray treatment $Ca_2Mg_{0.5}$ gave the maximum number of capsules per plant. However its effect was followed by that of Ca_2Mg_0. Spray treatment $Ca_2Mg_{0.5}$ increased capsules per plant by 76.0% over Ca_0Mg_0.

Table 93. Effect of foliar application of Ca and Mg on leaf Ca content (%) of linseed cultivars at two stages of growth (Mean of four replicates)

Treatments (T) (kg/ha)	Cultivars (Cv)			Mean
	Parvati	Shekhar	Shubhra	
		60 DAS		
Ca_0Mg_0	0.36	0.39	0.42	0.39
Ca_2Mg_0	0.52	0.58	0.63	0.58
$Ca_0Mg_{0.5}$	0.34	0.37	0.39	0.37
$Ca_2Mg_{0.5}$	0.42	0.49	0.54	0.48
Mean	0.41	0.46	0.50	
CD at 5%	T= 0.05	Cv = 0.05	T x Cv = 0.09	
		75 DAS		
Ca_0Mg_0	0.43	0.46	0.51	0.47
Ca_2Mg_0	0.60	0.65	0.73	0.66
$Ca_0Mg_{0.5}$	0.40	0.42	0.47	0.43
$Ca_2Mg_{0.5}$	0.52	0.57	0.61	0.57
Mean	0.49	0.53	0.58	
CD at 5%	T = 0.04	Cv = 0.04	T x Cv = 0.07	

NB: A uniform pre-sowing seed and foliar treatment of 10^{-6}M GA_3 as well as a basal dose of $N_{60}P_{20}K_{30}$ was applied.

Table 94. Effect of foliar application of Ca and Mg on leaf Mg content (%) of linseed cultivars at two stages of growth (Mean of four replicates)

Treatments (T) (kg/ha)	Cultivars (Cv)			Mean
	Parvati	Shekhar	Shubhra	
		60 DAS		
Ca_0Mg_0	0.23	0.26	0.29	0.26
Ca_2Mg_0	0.20	0.24	0.26	0.23
$Ca_0Mg_{0.5}$	0.30	0.34	0.37	0.34
$Ca_2Mg_{0.5}$	0.27	0.32	0.34	0.31
Mean	0.25	0.29	0.32	
CD at 5%	T= 0.05	Cv = 0.04	T x Cv = 0.07	
		75 DAS		
Ca_0Mg_0	0.31	0.36	0.38	0.35
Ca_2Mg_0	0.27	0.32	0.35	0.31
$Ca_0Mg_{0.5}$	0.43	0.45	0.48	0.45
$Ca_2Mg_{0.5}$	0.35	0.39	0.41	0.38
Mean	0.34	0.38	0.41	
CD at 5%	T = 0.05	Cv = 0.04	T x Cv = 0.08	

NB: A uniform pre-sowing seed and foliar treatment of 10^{-6}M GA_3 as well as a basal dose of $N_{60}P_{20}K_{30}$ was applied.

Of cultivars, Shubhra proved best, with Shekhar following it. Cultivar Shubhra gave 16.1% higher value than Parvati which gave the lowest value.

Interaction $Ca_2Mg_{0.5}$ x Shubhra gave the maximum value. Its effect was followed by that of Ca_2Mg_0 x Shubhra, $Ca_2Mg_{0.5}$ x Shekhar and $Ca_0Mg_{0.5}$ x Shubhra. Interaction $Ca_2Mg_{0.5}$ x Shubhra increased capsules per plant by 108.7% over Ca_0Mg_0 x Parvati which gave the lowest value (Table 95).

4.5.3.2 Seeds per capsule

The effect of treatments on seeds per capsule was not significant.

Cultivar Shubhra gave the maximum number of seeds per capsule, with Parvati being at par with it. Cultivar Shubhra gave 1.3% higher value than Parvati which gave the minimum value.

Interaction effect on this parameter did not vary (Table 95).

4.5.3.3 1000-seed weight

Spray treatment $Ca_2Mg_{0.5}$ gave the heaviest seeds, however its effect was equalled by that of Ca_2Mg_0. Spray treatment $Ca_2Mg_{0.5}$ improved 1000-seed weight by 5.4% over Ca_0Mg_0.

Cultivar Shubhra gave the maximum value for this yield parameter, with Shekhar occupying the second position. Cultivar Shubhra gave 7.4% higher value than Parvati which gave the lowest value.

Interaction $Ca_2Mg_{0.5}$ x Shubhra gave the maximum value for 1000-seed weight. However, its effect was equalled by that of Ca_2Mg_0 x Shubhra, $Ca_0Mg_{0.5}$ x Shubhra, $Ca_2Mg_{0.5}$ x Shekhar and Ca_2Mg_0 x Shekhar. Interaction $Ca_2Mg_{0.5}$ x Shubhra gave 14.2% higher value than Ca_0Mg_0 x Parvati which gave the lowest value (Table 96).

4.5.3.4 Seed yield per plant

Spray treatment $Ca_2Mg_{0.5}$ gave the maximum value for this yield characteristic. Its effect was followed by that of Ca_2Mg_0 and $Ca_0Mg_{0.5}$. Spray treatment $Ca_2Mg_{0.5}$ gave 39.6% higher value than Ca_0Mg_0.

Among cultivars, Shubhra gave the maximum number of seeds per plant, with Shekhar following it. Shubhra gave 14.1% higher value than Parvati which gave the lowest value.

Table 95. Effect of foliar application of Ca and Mg on capsules per plant and seeds per capsule of linseed cultivars at harvest (Mean of four replicates)

Treatments (T) (kg/ha)	Cultivars (Cv)			Mean
	Parvati	Shekhar	Shubhra	
		Capsules per plant		
Ca_0Mg_0	73.00	85.00	80.67	79.56
Ca_2Mg_0	119.33	126.67	139.00	128.33
$Ca_0Mg_{0.5}$	112.67	119.33	131.67	121.22
$Ca_2Mg_{0.5}$	129.00	138.67	152.33	140.00
Mean	108.50	117.42	125.92	
CD at 5%	T= 5.65	Cv = 4.90	T x Cv = 9.79	
		Seeds per capsule		
Ca_0Mg_0	8.60	7.72	8.57	8.30
Ca_2Mg_0	8.66	7.93	8.83	8.47
$Ca_0Mg_{0.5}$	8.64	8.11	8.50	8.42
$Ca_2Mg_{0.5}$	8.75	8.26	9.17	8.73
Mean	8.66	8.01	8.77	
CD at 5%	T = NS	Cv = 0.74	T x Cv = NS	

NB: A uniform pre-sowing seed and foliar treatment of 10^{-6}M GA_3 as well as a basal dose of $N_{60}P_{20}K_{30}$ was applied.

NS = Non-significant

Table 96. Effect of foliar application of Ca and Mg on 1000-seed weight and seed yield per plant of linseed cultivars at harvest (Mean of four replicates)

Treatments (T) (kg/ha)	Cultivars (Cv)			Mean
	Parvati	Shekhar	Shubhra	
	1000-seed weight (g)			
Ca_0Mg_0	8.60	9.07	9.36	9.01
Ca_2Mg_0	9.11	9.44	9.71	9.42
$Ca_0Mg_{0.5}$	8.86	9.35	9.55	9.25
$Ca_2Mg_{0.5}$	9.23	9.46	9.82	9.50
Mean	8.95	9.33	9.61	
CD at 5%	T= 0.22	Cv = 0.19	T x Cv = 0.38	
	Seed yield per plant (g)			
Ca_0Mg_0	2.71	2.93	3.15	2.93
Ca_2Mg_0	3.40	3.51	3.78	3.56
$Ca_0Mg_{0.5}$	3.23	3.37	3.61	3.40
$Ca_2Mg_{0.5}$	3.74	4.15	4.37	4.09
Mean	3.27	3.49	3.73	
CD at 5%	T = 0.17	Cv = 0.15	T x Cv = 0.29	

NB: A uniform pre-sowing seed and foliar treatment of 10^{-6}M GA_3 as well as a basal dose of $N_{60}P_{20}K_{30}$ was applied.

Interaction $Ca_2Mg_{0.5}$ x Shubhra gave the maximum seed yield per plant. Its effect was equalled by that of $Ca_2Mg_{0.5}$ x Shekhar. Interaction $Ca_2Mg_{0.5}$ x Shubhra gave 61.3% higher value than Ca_0Mg_0 x Parvati which gave the lowest value (Table 96).

4.5.3.5 Biological yield per plant

Spray treatment $Ca_2Mg_{0.5}$ gave the maximum biological yield per plant. Its effect was followed by that of Ca_2Mg_0 and $Ca_0Mg_{0.5}$. Spray treatment $Ca_2Mg_{0.5}$ gave 33.5% higher value than Ca_0Mg_0.

Cultivar differences were not significant for this yield characteristic.

Regarding interactions, $Ca_2Mg_{0.5}$ x Shekhar gave the maximum value. Its effect was equalled by that of $Ca_2Mg_{0.5}$ x Shubhra, $Ca_2Mg_{0.5}$ x Parvati and Ca_2Mg_0 x Shubhra. Interaction $Ca_2Mg_{0.5}$ x Shubhra gave 45.8% higher value than Ca_0Mg_0 x Parvati which gave the lowest value (Table 97).

4.5.3.6 Harvest index

Spray treatment $Ca_2Mg_{0.5}$ gave the maximum value for harvest index. However, its effect was at par with that of Ca_2Mg_0 and $Ca_0Mg_{0.5}$. Spray treatment $Ca_2Mg_{0.5}$ gave 4.4% higher value than Ca_0Mg_0.

Of cultivars, Shubhra proved best. It was followed by Shekhar and Parvati. Cultivar Shubhra gave 6.2% higher value than Parvati which gave the lowest value.

Interaction $Ca_2Mg_{0.5}$ x Shubhra gave the maximum value for this parameter. However, its effect was at par with that of Ca_2Mg_0 x Shubhra and $Ca_0Mg_{0.5}$ x Shubhra. Interaction $Ca_2Mg_{0.5}$ x Shubhra gave 10.6% higher value than Ca_0Mg_0 x Partvati which gave the lowest value (Table 97).

4.5.3.7 Oil content

The effect of treatments on oil content of seeds was not significant.

Among cultivars, Shubhra gave the maximum value, Shekhar being at par with it. Cultivar Shubhra gave 4.6% higher value than Parvati which gave the lowest value.

As for spray treatments, interaction effect on oil content was also not significant (Table 98).

Table 97. Effect of foliar application of Ca and Mg on biological yield per plant and harvest index of linseed cultivars at harvest (Mean of four replicates)

Treatments (T) (kg/ha)	Cultivars (Cv)			Mean
	Parvati	Shekhar	Shubhra	
		Biological yield per plant (g)		
Ca_0Mg_0	10.61	11.45	12.02	11.36
Ca_2Mg_0	13.21	13.34	13.69	13.41
$Ca_0Mg_{0.5}$	12.52	12.85	13.11	12.83
$Ca_2Mg_{0.5}$	14.33	15.71	15.47	15.17
Mean	12.67	13.34	13.57	
CD at 5%	T= 1.23	Cv = NS	T x Cv = 2.13	
		Harvest index (%)		
Ca_0Mg_0	25.53	25.60	26.21	25.78
Ca_2Mg_0	25.74	26.31	27.61	26.55
$Ca_0Mg_{0.5}$	25.80	26.23	27.53	26.52
$Ca_2Mg_{0.5}$	26.10	26.41	28.24	26.92
Mean	25.79	26.14	27.40	
CD at 5%	T = 0.69	Cv = 0.60	T x Cv = 1.19	

NB: A uniform pre-sowing seed and foliar treatment of 10^{-6}M GA_3 as well as a basal dose of $N_{60}P_{20}K_{30}$ was applied.

NS = Non-significant

Table 98. Effect of foliar application of Ca and Mg on oil content and oil yield per plant of linseed cultivars at harvest (Mean of four replicates)

Treatments (T) (kg/ha)	Cultivars (Cv)			Mean
	Parvati	Shekhar	Shubhra	
		Oil content (%)		
Ca_0Mg_0	38.15	38.10	39.47	38.57
Ca_2Mg_0	38.31	39.47	39.68	39.15
$Ca_0Mg_{0.5}$	39.06	40.31	41.26	40.21
$Ca_2Mg_{0.5}$	39.15	39.86	41.32	40.11
Mean	38.67	39.44	40.43	
CD at 5%	T= NS	Cv = 1.66	T x Cv = NS	
		Oil yield per plant (g)		
Ca_0Mg_0	1.03	1.12	1.24	1.13
Ca_2Mg_0	1.30	1.39	1.50	1.40
$Ca_0Mg_{0.5}$	1.26	1.36	1.49	1.37
$Ca_2Mg_{0.5}$	1.46	1.72	1.81	1.66
Mean	1.26	1.40	1.51	
CD at 5%	T = 0.14	Cv = 0.13	T x Cv = 0.25	

NB: A uniform pre-sowing seed and foliar treatment of 10^{-6}M GA_3 as well as a basal dose of $N_{60}P_{20}K_{30}$ was applied.

NS = Non-significant

4.5.3.8 Oil yield per plant

Spray treatment $Ca_2Mg_{0.5}$ gave the maximum oil yield per plant. Its effect was followed by that of Ca_2Mg_0 and $Ca_0Mg_{0.5}$. Spray treatment $Ca_2Mg_{0.5}$ gave 46.9% higher value than Ca_0Mg_0.

Cultivars Shubhra and Shekhar, being at par, gave higher value than Parvati. Cultivar Shubhra gave 19.8% higher value than Parvati.

Of interactions, $Ca_2Mg_{0.5}$ x Shubhra gave the maximum value, with its effect being at par with that of $Ca_2Mg_{0.5}$ x Shekhar. Interaction $Ca_2Mg_{0.5}$ x Shubhra gave 75.7% higher value than Ca_0Mg_0 x Parvati which gave the lowest value (Table 98).

4.5.3.9 Iodine value

The effect of spray treatments and their interactions with cultivars on iodine value of the oil, as also cultivar differences, were not significant (Table 99).

4.5.3.10 Fibre yield per plant

Spray treatment $Ca_2Mg_{0.5}$ gave the maximum fibre yield per plant. Its effect was followed by that of $Ca_0Mg_{0.5}$ and Ca_2Mg_0. Spray treatment $Ca_2Mg_{0.5}$ increased fibre yield per plant by 36.9% over Ca_0Mg_0.

Of cultivars, Shubhra proved best, with Shekhar following it. Cultivar Shubhra gave 6.2% higher value than Parvati which gave the lowest value.

Among interactions, $Ca_2Mg_{0.5}$ x Shubhra gave the maximum value. However, its effect was equalled by that of $Ca_2Mg_{0.5}$ x Shekhar, $Ca_2Mg_{0.5}$ x Parvati and Ca_2Mg_0 x Shubhra. Interaction $Ca_2Mg_{0.5}$ x Shubhra gave 44.1% higher value than Ca_0Mg_0 x Parvati which gave the lowest value (Table 100).

4.5.3.11 Lodging

Foliar spray treatment Ca_0Mg_0 gave the maximum value for this parameter. However, its effect was at par with that of $Ca_0Mg_{0.5}$. Spray treatment Ca_0Mg_0 gave 16.2% higher value than $Ca_2Mg_{0.5}$ which gave the lowest value.

Of cultivars, Parvati gave the maximum value. It was followed by Shekhar and Shubhra. Cultivar Parvati gave 24.7% higher value than Shubhra which exhibited the lowest value.

Table 99. Effect of foliar application of Ca and Mg on iodine value of linseed cultivars at harvest (Mean of four replicates)

Treatments (T) (kg/ha)	Cultivars (Cv)			Mean
	Parvati	Shekhar	Shubhra	
		Iodine value		
Ca_0Mg_0	181.62	187.41	183.35	184.13
Ca_2Mg_0	186.57	184.33	186.60	185.83
$Ca_0Mg_{0.5}$	189.02	194.49	182.58	188.70
$Ca_2Mg_{0.5}$	194.25	206.00	189.33	196.53
Mean	187.87	193.06	185.47	
CD at 5%	T= NS	Cv = NS	T x Cv = NS	

NB: A uniform pre-sowing seed and foliar treatment of 10^{-6}M GA_3 as well as a basal dose of $N_{60}P_{20}K_{30}$ was applied.

NS = Non-significant

Table 100. Effect of foliar application of Ca and Mg on fibre yield per plant of linseed cultivars at harvest (Mean of four replicates)

Treatments (T) (kg/ha)	Cultivars (Cv)			Mean
	Parvati	Shekhar	Shubhra	
	Fibre yield per plant (g)			
Ca_0Mg_0	1.309	1.374	1.386	1.356
Ca_2Mg_0	1.616	1.659	1.815	1.697
$Ca_0Mg_{0.5}$	1.720	1.738	1.752	1.737
$Ca_2Mg_{0.5}$	1.819	1.862	1.886	1.856
Mean	1.616	1.658	1.710	
CD at 5%	T= 0.047	Cv = 0.041	T x Cv = 0.081	

NB: A uniform pre-sowing seed and foliar treatment of 10^{-6}M GA_3 as well as a basal dose of $N_{60}P_{20}K_{30}$ was applied.

Among interactions, $Ca_0Mg_{0.5}$ x Parvati gave the maximum value. However, its effect was at par with that of Ca_0Mg_0 x Parvati, Ca_2Mg_0 x Parvati and $Ca_2Mg_{0.5}$ x Parvati. Interaction $Ca_0Mg_{0.5}$ x Parvati gave 55.9% higher value than $Ca_2Mg_{0.5}$ x Shubhra which exhibited the minimum value (Table 101).

4.6 Conclusion

From the foregoing results, the following points emerged and these could be claimed as first report in the literature:

(1) The performance of five cultivars of linseed, namely Laxmi 27, Parvati, Rashmi, Shekhar and Shubhra, has been studied in relation to pre-sowing seed and foliar spray treatment of GA_3 in the presence of the recommended dose of $N_{90}P_{30}K_{30}$.

Among the five cultivars, Shubhra, followed by Parvati and Shekhar in respect of seed and oil yield, gave the maximum value for most parameters. However, Laxmi 27 and Rashmi registered the minimum value.

Keeping the performance of cultivars in view, three cultivars, namely Parvati, Shekhar and Shubhra, were retained in Experiments 2-5. In these trials, Shubhra repeatedly performed best and Parvati least.

Pre-sowing seed plus foliar spray treatment with 10^{-6}M GA_3 gave the maximum value for most parameters particularly in case of Shubhra. However, 0 M GA_3 x Laxmi 27 exhibited the lowest value.

(2) The optimum requirement of the three better performing cultivars of linseed for basal N and P (with a uniform dose of K_{30}) was determined in the presence of best combination of pre-sowing seed and foliar spray treatment of GA_3 (10^{-6} M).

Basal combination $N_{60}P_{20}$ especially with Shubhra, gave the maximum value for most parameters, whereas, N_0P_0 x Parvati registered the minimum values.

(3) The effect of foliar application of Ca and/or Mg has been studied on the performance of the three better performing cultivars of linseed grown with the best combination of pre-sowing seed treatment and foliar spray of GA_3 (10^{-6} M) and $N_{60}P_{20}$ level of basal N and P, with a uniform dose of K_{30}.

Table 101. Effect of foliar application of Ca and Mg on lodging of linseed cultivars at harvest (Mean of four replicates)

Treatments (T) (kg/ha)	Cultivars (Cv)			Mean
	Parvati	Shekhar	Shubhra	
		Lodging (%)		
Ca_0Mg_0	33.7	30.0	29.0	30.9
Ca_2Mg_0	32.0	24.7	26.3	27.7
$Ca_0Mg_{0.5}$	34.3	29.3	27.7	30.4
$Ca_2Mg_{0.5}$	31.0	26.7	22.0	26.6
Mean	32.8	27.7	26.3	
CD at 5%	T= 1.90	Cv = 1.82	T x Cv = 3.63	

NB: A uniform pre-sowing seed and foliar treatment of 10^{-6}M GA_3 as well as a basal dose of $N_{60}P_{20}K_{30}$ was applied.

Foliar spray of $Ca_2Mg_{0.5}$ particularly on Shubhra plants proved best for most parameters. On the other hand, Ca_0Mg_0 x Parvati gave the lowest values.

Spray of $Ca_2Mg_{0.5}$ decreased lodging of Shubhra plants considerably, being about 35% of the (maximum) lodging noted in the combinations $Mg_{0.5}$ x Parvati and Ca_0Mg_0 x Parvati, presumably due to their involvement in the constitution of fibres in the form of pectates leading to provide mechanical strength.

(4) Lastly, the factors contributing to the maximization of seed and oil yield and fibre yield are the increase in (i) height per plant, (ii) leaf area per plant, (iii) leaf area index, (iv) fresh weight per plant, (v) dry weight per plant, (vi) net photosynthetic rate, (vii) carbonic anhydrase activity, (viii) chlorophyll content, (ix) leaf Ca and Mg content, (x) capsules per plant and (xi) 1000-seed weight. This conclusion is not only based on the data but also on computation of coefficients of correlation.

To put the above in a nut shell, it may be concluded that the genetic potential of linseed cultivar Shubhra could be realised maximally if it is given pre-sowing seed treatment of 10^{-6}M GA_3 and combined foliar spray of 10^{-6}M GA_3 + 2 kg Ca/ha + 0.5 kg Mg/ha at 40 DAS in the presence of a basal dose of 60 kg N + 20 kg P + 30 kg K/ha which could save costly fertilizer also and is, therefore, cost effective.

Discussion

CONTENTS

DISCUSSION

Plant hormones are known to play a crucial role in controlling the way in which plants grow and develop. GA_3 is one of the important phytohormones. It has been shown to regulate many facets of plant life, including seed germination, vegetative growth and differentiation (De-La-Guardia and Benlloch, 1980; Ray and Choudhuri, 1981; Bangal *et al.*, 1982; Simpson *et al.*, 1982; Erdel and Dhakal, 1988; Singh and Sahu, 1993; Agrawal *et al.*, 1994; Khan *et al.*, 1996; Khan and Samiullah, 2003; Azam, 2003; Siddiqui and Mohammad, 2003; Afroz *et al.*, 2005; Khan *et al.*, 2006). In view of its role in growth and development of plants and very low concentration involved (cost effectiveness), it is logical to include GA_3 in innovative farm practices.

The growth rate and productivity of plants are determined mainly by their capacity to assimilate C in the source organs followed by the utilization of the photosynthates partly for growth and development and lastly for storage in the sink organs. As this capacity is affected to a great extent by mineral nutrients, among other factors, their deficiency substantially impairs production of dry matter and its partitioning between the plant organs (Geiger *et al.*, 1996; Marschner *et al.*, 1996; Mc Donald *et al.*, 1996; Marschner, 2002). Thus, an increase in growth by any means (GA_3 treatment in the present study) would require an additional amount of mineral nutrients. It is, therefore, highly desirable to work out the precise dose of nutrients for plants receiving GA_3 treatment.

GA_3 treatment induces stem elongation. The elongation may be of such a magnitude that it causes lodging leading to some loss of yield. However, this loss could be minimized if the treated plants are provided mechanical strength endogenously. One approach, in this direction, may be to strengthen middle lamellae by their constituent mineral elements.

Keeping these points in view, five pot experiments have been conducted on linseed under the agroclimatic conditions of Aligarh. The Experiments were so designed as to determine beyond doubt whether or not seed and foliar treatment of linseed with GA_3, combined with judicious fertilizer management could be exploited economically to increase the productivity of this important oilseed crop. The performance of the crop has been assessed in terms of growth characteristics, physiological and biochemical parameters as also yield and quality characteristics. The results have been discussed parameter-wise in the light of the knowledge of the subject and research work carried out by other workers.

5.1 Growth characteristics

5.1.1 Effect of treatments

The ameliorative effect of seed and foliar spray treatments with GA_3, particularly at 10^{-6} M GA_3, over the water-sprayed control on plant height and leaf area of plants, receiving the officially recommended basal dose of N, P and K ($N_{90}P_{30}K_{30}$), at 60 and 75 DAS in Experiment 1 (Tables 8 and 9) can be traced to its various roles in plants. For example, treatment with GA_3 enhances, among other processes, absorption of nutrients (Balki and Padole, 1982; Singh *et al.,* 2005), activity of enzymes (Khan, 1996; Chanda *et al.*, 1998; Yuan and Xu, 2001; Afroz *et al.*, 2005), cell division (Liu and Loy, 1976; Moore, 1989; Huttly and Phillips, 1995; Arteca, 1996), cell enlargement and differentiation (Huttly and Phillips, 1995; Mobin, 1999; Buchanan *et al.*, 2000; Marschner, 2002), chlorophyll content (Afroz *et al.*, 2005), deoxyribose nucleic acid, ribose nucleic acid and protein synthesis (Broughton, 1968; Johri and Varner, 1968; Roth-Bejerano and Lips, 1970; Pain and Dutta, 1977; Mozer, 1980), activity of ribulose bisphosphate carboxylase, a key enzyme controlling photosynthetic carbon fixation of plants (Yuan and Xu, 2001), synthesis of other enzymes, especially hydrolases (Marschner, 2002), membrane permeability (Wood and Paleg, 1972; 1974; Crozier and Turnbull, 1984), elongation of internode (Krishnamoorthy, 1981; Kumar *et al.,* 1996), metabolism of storage products (Mobin, 1999), nitrogen use efficiency (Khan *et al.*, 2002), P_N (Afroz *et al.*, 2005), ribose and polyribose multiplication (Evins and Varner, 1972), synthesis of new materials (Mobin, 1999) and transport of photosynthates (Mulligan and Patrick, 1979; Aloni *et al.*, 1986; Daie *et al.*, 1986; Estruch *et al.*, 1989; Hayat *et al.*, 2001). The cumulative effect of the seed treatment before sowing and foliar spray at the crucial stage with GA_3 could have led to the observed improvement in plant height and leaf area of the treated plants. These results broadly corroborate the findings of earlier workers, including Saran *et al.*(1992), Khan (1996), Khan *et al.* (1996, 1998), Chanda *et al.* (1998), Khan *et al.* (2002), Khan and Samiullah (2003) and Afroz *et al.* (2005) on mustard.

The considerable increase in plant height and leaf area of plants due to application of N and P, particularly $N_{60}P_{20}$, (with the uniform dose of K_{30}) over the no nutrient control (Tables 26 and 27, Experiment 2) grown with a uniform pre-sowing seed and foliar treatment of GA_3 at 10^{-6} M is not far to seek. The promoting effect of N and P on these parameters of linseed can be explained on the basis of the fact that N functions as a component of a number of metabolites, including amino acids, chlorophylls, co-enzymes, enzymes, proteins, purines and pyrimidines. P also plays an important role in various metabolic processes as it is an integral part of several compounds, such as co-enzymes, nucleic acids, nucleotides, phospholipids, phosphoric acids, phosphorylated sugars and sugar phospholipids (Marschner, 2002). Moreover, N is known to increase levels of cytokinin which affects cell wall extensibility (Wagner and Michael, 1971; Salama and Wareing, 1979; Rayle *et al.*, 1982). Thus, N and P are involved directly or indirectly in the production and enlargement of new cells and tissues which in turn are responsible for increase in height (Table 26) and leaf area (Table 27) of treated plants. A beneficial effect of external supply of N and P on growth parameters of this crop has also been reported by Khare *et al.* (1995, 1996), Samui *et al.* (1995), Sharma *et al.* (1997), Singh and Verma (1997, 1999), Mohammad and Siddiqui (1999), Badiyala and Sharma (2000), Dubey (2001) and Badiyala and Kumar (2003). It is noteworthy that a dose of N and P ($N_{60}P_{20}$) lower than the recommended one seems to be sufficient for the optimum values for these two parameters (Tables 26 and 27), when the plants were treated with the proper dose of GA_3.

The ameliorative effect of the foliar spray of Ca and/or Mg (particularly 2 kg Ca and/or 0.5 kg Mg/ha) over the water-treated control at both sampling stages on plant height and leaf area per plant of the crop (Tables 44, 45, 63, 64, 82 and 83; Experiments 3-5) grown with the uniform pre-sowing seed and foliar treatment with 10^{-6}M GA_3 (selected from Experiment 1) and dose of $N_{60}P_{20}$ (determined in Experiment 2) is a wholesome observation. The promoting effect of Ca and Mg on the growth parameters can be traced to their various roles. For instance, Ca (a) acts as an activator of many enzymes, including adenosine triphosphate, adenyl kinase, alpha amylase, arginine kinase, phospholipase and potatoapyrase, and a second messenger; (b) aids in neutralizing acids, especially oxalic acid which might limit growth; (c) enters the cell wall and forms calcium pectate; (d) helps in figuration of growing tips of roots and shoots; (e) is involved in availability of other nutrients, mitochondrion and plasma membrane formation, mitotic cell division, cell elongation and tissue extensibility, regulation of activity of chloroplasts, signalling of chloroplast mechano-relocation and stabilization of electron transport, energy distribution between the two photosystems of photosynthesis, photophosphorylation and thylakoid membranes of chlorophylls; and (f) stimulates development of root hairs, movement and utilization of carbohydrates and amino acids and the process of photosynthesis (Wyn Jones and Lunt, 1967; Moll and Jones, 1981; Berridge *et al.*, 1998; Sato *et al.*, 2001; Marschner, 2002; Gardner *et al.*, 2003; Hirschi, 2004; Mukherji and Ghosh, 2005). Similarly, Mg is the constituent of the chlorophyll molecule; acts as a bridging element for the aggregation of ribosomes; and is essential for the function of many enzymes, including adenosine triphosphatases, carboxylases, fructose 1, 6-bisphosphatase, glutathione synthetase, phosphatases, protein kinases, ribonucleic acid polymerases and sedoheptulose 1, 7-bisphosphatase (Purczeld *et al.*, 1978; Gardemann *et al.*, 1986; Portis, 1992; Mengel and Kirkby, 1996). Thus, Ca and Mg take part directly or indirectly in the process of development of shoot and leaf, hence the observed enhancement in the values for these growth parameters. These results resemble those of other workers, including Singh and Gill (1987), Bose and Mishra (2001) and Shanker *et al.* (2001) on crops other than linseed.

The enhancement in plant height and leaf area provided opportunities for the plant with regard to better orientation of leaves and larger leaf area respectively for harvesting maximum solar energy. This sequence of events may ultimately lead to a positive effect on fresh and dry weight of treated plants (Tables 11, 12, 29, 30, 47, 48, 66, 67, 85 and 86). This is further confirmed by correlation studies as these two parameters have been found to be positively correlated with fresh and dry weight (Tables 102-106). Similar increase in dry matter production due to GA_3 treatment has been reported by Saran *et al.* (1992), Khan (1996), Khan *et al.* (1996, 2000), Khan and Samiullah (2003) and Afroz *et al.* (2005) on mustard; due to N and P dressing by Sharma *et al.* (1997), Singh and Verma (1997), Singh and Verma (1999), Badiyala and Sharma (2000), Dubey (2001) on linseed and on Ca and Mg application by Sharma and Kamath (1990), Tan *et al.* (1991), Khan *et al.* (2001) and Shanker *et al.* (2001) on plants other than linseed.

Table 102. Correlation coefficient (r) values for different pairs of characteristics of linseed in Experiment 1

Characteristics	Sampling stages (DAS)	Leaf area per plant		Leaf area index		Fresh weight per plant		Dry weight per plant		Net photosynthetic rate	
		Sampling stages (DAS)		Sampling stages (DAS)		Sampling stages (DAS)		Sampling stages (DAS)		Sampling stages (DAS)	
		60	75	60	75	60	75	60	75	60	75
Height per plant	60	0.984	–	0.983	–	0.986	–	0.993	–	0.966	–
	75	–	0.985	–	0.985	–	0.990	–	0.966	–	0.959
Leaf area per plant	60	–	–	0.999	–	0.999	–	0.998	–	0.997	–
	75	–	–	–	0.999	–	0.999	–	0.996	–	0.993
Leaf area index	60	–	–	–	–	0.999	–	0.998	–	0.997	–
	75	–	–	–	–	–	0.999	–	0.996	–	0.994
Fresh weight per plant	60	–	–	–	–	–	–	0.999	–	0.996	–
	75	–	–	–	–	–	–	–	0.993	–	0.990
Dry weight per plant	60	–	–	–	–	–	–	–	–	0.990	–
	75	–	–	–	–	–	–	–	–	–	0.999

Contd...

	r value
Significant at 5%	0.514
Significant at 1%	0.641

Table 102 (Contd). Correlation coefficient (r) values for different pairs of characteristics of linseed in Experiment 1

Characteristics	Sampling stages (DAS)	Carbonic anhydrase activity		Leaf chlorophyll content		Leaf N content		Leaf P content		Leaf K content	
		Sampling stages (DAS)		Sampling stages (DAS)		Sampling stages (DAS)		Sampling stages (DAS)		Sampling stages (DAS)	
		60	75	60	75	60	75	60	75	60	75
Height	60	0.996	–	0.964	–	–	–	0.999	–	0.982	–
per plant	75	–	0.979	–	0.977	–	0.997	–	0.999	–	0.958
Leaf area	60	0.963	–	0.996	–	0.984	–	0.989	–	0.999	–
per plant	75	–	0.930	–	0.999	–	0.970	–	0.986	–	0.993
Leaf area	60	0.962	–	0.996	–	0.983	–	0.988	–	0.999	–
index	75	–	0.928	–	0.999	–	0.969	–	0.985	–	0.993
Fresh weight	60	0.966	–	0.995	–	0.986	–	0.991	–	0.999	–
per plant	75	–	0.940	–	0.998	–	0.977	–	0.990	–	0.989
Dry weight	60	0.977	–	0.989	–	0.993	–	0.996	–	0.998	–
per plant	75	–	0.892	–	0.999	–	0.944	–	0.967	–	0.999

Contd…

	r value
Significant at 5%	0.514
Significant at 1%	0.641

Table 102 (Contd.). Correlation coefficient (r) values for different pairs of characteristics of linseed in Experiment 1

Characteristics	Sampling stages (DAS)	Capsules per plant	Seeds per capsule	1000-seed weight	Seed yield per plant	Biological yield per plant	Harvest index
Height per plant	60	0.947	0.686	0.739	0.999	0.997	0.866
	75	0.952	0.696	0.749	0.999	0.995	0.873
Leaf area per plant	60	0.989	0.805	0.848	0.987	0.966	0.942
	75	0.990	0.809	0.851	0.986	0.964	0.944
Leaf area index	60	0.990	0.806	0.849	0.987	0.965	0.942
	75	0.991	0.811	0.853	0.986	0.963	0.945
Fresh weight per plant	60	0.987	0.797	0.841	0.989	0.969	0.937
	75	0.986	0.792	0.836	0.991	0.971	0.934
Dry weight per plant	60	0.979	0.768	0.815	0.995	0.980	0.920
	75	0.999	0.859	0.896	0.967	0.936	0.970

Contd…

	r value
Significant at 5%	0.514
Significant at 1%	0.641

Table 102 (Contd.). Correlation coefficient (r) values for different pairs of characteristics of linseed in Experiment 1

Characteristics	Sampling stages (DAS)	Oil content	Oil yield per plant	Iodine value	Fibre yield per plant	Lodging
Height per plant	60	0.878	0.998	-0.988	0.994	0.919
	75	0.885	0.999	-0.990	0.995	0.924
Leaf area per plant	60	0.950	0.993	-0.999	0.998	0.975
	75	0.952	0.992	-0.999	0.997	0.976
Leaf area index	60	0.950	0.993	-0.999	0.998	0.975
	75	0.953	0.992	-0.999	0.997	0.977
Fresh weight per plant	60	0.945	0.994	-0.999	0.999	0.972
	75	0.942	0.995	-0.999	0.999	0.969
Dry weight per plant	60	0.929	0.998	-0.999	0.999	0.960
	75	0.976	0.976	-0.992	0.986	0.992

Contd...

	r value
Significant at 5%	0.514
Significant at 1%	0.641

Table 102 (Contd.). Correlation coefficient (r) values for different pairs of characteristics of linseed in Experiment 1

Characteristics	Sampling stages (DAS)	Carbonic anhydrase activity		Leaf chlorophyll content		Leaf N content		Leaf P content		Leaf K content	
		Sampling stages (DAS)		Sampling stages (DAS)		Sampling stages (DAS)		Sampling stages (DAS)		Sampling stages (DAS)	
		60	75	60	75	60	75	60	75	60	75
Net photosynthetic rate	60	0.938	–	0.999	–	0.966	–	0.973	–	0.997	–
	75	–	0.881	–	0.997	–	0.936	–	0.960	–	–
Carbonic anhydrase activity	60	–	–	0.935	–	0.996	–	0.992	–	0.960	–
	75	–	–	–	0.914	–	0.991	–	0.978	–	0.880
Leaf chlorophyll content	60	–	–	–	–	0.964	–	0.972	–	0.997	–
	75	–	–	–	–	–	0.959	–	0.978	–	0.997
Leaf N content	60	–	–	–	–	–	–	0.999	–	0.982	–
	75	–	–	–	–	–	–	–	0.997	–	0.935
Leaf P content	60	–	–	–	–	–	–	–	–	0.987	–
	75	–	–	–	–	–	–	–	–	–	0.959
Leaf K content	60	–	–	–	–	–	–	–	–	–	–
	75	–	–	–	–	–	–	–	–	–	–

Contd…

	r value
Significant at 5%	0.514
Significant at 1%	0.641

Table 102 (Contd.). Correlation coefficient (r) values for different pairs of characteristics of linseed in Experiment 1

Characteristics	Sampling stages (DAS)	Capsules per plant	Seeds per capsule	1000-seed weight	Seed yield per plant	Biological yield per plant	Harvest index
Net photosynthetic rate	60	0.998	0.850	0.888	0.971	0.942	0.966
	75	0.999	0.871	0.906	0.961	0.927	0.975
Carbonic anhydrase activity	60	0.913	0.614	0.673	0.994	0.999	0.815
	75	0.870	0.535	0.598	0.978	0.994	0.756
Leaf chlorophyll content	60	0.998	0.854	0.891	0.969	0.940	0.967
	75	0.995	0.832	0.872	0.978	0.952	0.957
Leaf N content	60	0.947	0.686	0.739	0.999	0.997	0.866
	75	0.927	0.642	0.699	0.997	0.999	0.835
Leaf P content	60	0.956	0.707	0.759	0.999	0.994	0.881
	75	0.953	0.699	0.752	–	0.995	0.875
Leaf K content	60	0.991	0.811	0.853	0.985	0.963	0.945
	75	0.999	0.873	0.907	0.960	0.926	0.976

Contd…

	r value
Significant at 5%	0.514
Significant at 1%	0.641

Table 102 (Contd.). Correlation coefficient (r) values for different pairs of characteristics of linseed in Experiment 1

Characteristics	Sampling stages (DAS)	Oil content	Oil yield per plant	Iodine value	Fibre yield per plant	Lodging
Net photosynthetic rate	60	0.972	0.980	-0.994	0.989	0.990
	75	0.981	0.971	-0.989	0.982	0.995
Carbonic anhydrase activity	60	0.829	0.988	-0.969	0.979	0.878
	75	0.772	0.969	-0.941	0.955	0.827
Leaf chlorophyll content	60	0.973	0.979	-0.994	0.988	0.990
	75	0.964	0.986	-0.997	0.993	0.984
Leaf N content	60	0.878	0.998	-0.988	0.994	0.919
	75	0.849	0.993	-0.977	0.985	0.894
Leaf P content	60	0.892	0.999	-0.992	0.997	0.930
	75	0.887	0.999	-0.991	0.996	0.926
Leaf K content	60	0.953	0.992	-0.999	0.997	0.977
	75	0.981	0.970	-0.989	0.981	0.995

Contd…

	r value
Significant at 5%	0.514
Significant at 1%	0.641

Table 102 (Contd.). Correlation coefficient (r) values for different pairs of characteristics of linseed in Experiment 1

Characteristics	Seeds per capsule	1000-seed weight	Seed yield per plant	Biological yield per plant	Harvest index	Oil content	Oil yield per plant	Iodine value	Fibre yield per plant	Lodging
Capsules per plant	0.883	0.916	0.954	0.918	0.981	0.985	0.965	-0.985	0.977	0.997
Seeds per capsule	–	0.752	0.700	0.624	0.958	0.950	0.728	-0.789	0.763	0.917
1000-seed weight	–	–	0.752	0.682	0.977	0.971	0.778	-0.834	0.810	0.945
Seed yield per plant	–	–	–	0.995	0.876	0.887	0.999	-0.991	0.996	0.926
Biological yield per plant	–	–	–	–	0.822	0.836	0.990	-0.972	0.981	0.883
Harvest index	–	–	–	–	–	0.999	0.894	-0.933	0.917	0.993
Oil content	–	–	–	–	–	–	0.905	-0.941	0.926	0.996
Oil yield per plant	–	–	–	–	–	–	–	-0.996	0.999	0.941
Iodine value	–	–	–	–	–	–	–	–	-0.999	-0.969
Fibre yield per plant	–	–	–	–	–	–	–	–	–	0.957

	r value
Significant at 5%	0.514
Significant at 1%	0.641

Table 103. Correlation coefficient (r) values for different pairs of characteristics of linseed in Experiment 2

Characteristics	Sampling stages (DAS)	Leaf area per plant		Leaf area index		Fresh weight per plant		Dry weight per plant		Net photosynthetic rate	
		Sampling stages (DAS)		Sampling stages (DAS)		Sampling stages (DAS)		Sampling stages (DAS)		Sampling stages (DAS)	
		60	75	60	75	60	75	60	75	60	75
Height per plant	60	0.990	–	0.989	–	0.999	–	0.978	–	0.966	–
	75	–	0.965	–	0.977	–	0.969	–	0.969	–	0.975
Leaf area per plant	60	–	–	–	–	0.996	–	0.998	–	0.992	–
	75	–	–	–	0.999	–	0.999	–	0.999	–	0.994
Leaf area index	60	–	–	–	–	0.996	–	0.998	–	0.993	
	75	–	–	–	–	–	0.999	–	0.999	–	0.996
Fresh weight per plant	60	–	–	–	–	–	–	0.988	–	0.979	–
	75	–	–	–	–	–	–	–	0.999	–	0.995
Dry weight per plant	60	–	–	–	–	–	–		–	0.998	–
	75	–	–	–	–	–	–		–	–	0.996

Contd…

	r value
Significant at 5%	0.576
Significant at 1%	0.708

Table 103 (Contd). Correlation coefficient (r) values for different pairs of characteristics of linseed in Experiment 2

Characteristics	Sampling stages (DAS)	Carbonic anhydrase activity		Leaf chlorophyll content		Leaf N content		Leaf P content		Leaf K content	
		Sampling stages (DAS)		Sampling stages (DAS)		Sampling stages (DAS)		Sampling stages (DAS)		Sampling stages (DAS)	
		60	75	60	75	60	75	60	75	60	75
Height per plant	60	0.972	–	0.977	–	0.983	–	0.888	–	0.941	–
	75	–	0.981	–	0.974	–	0.977	–	0.955	–	0.983
Leaf area per plant	60	0.992	–	0.988	–	0.989	–	0.911	–	0.976	–
	75	–	0.990	–	0.992	–	0.973	–	0.946	–	0.970
Leaf area index	60	0.992	–	0.989	–	0.989	–	0.912	–	0.977	–
	75	–	0.993	–	0.994	–	0.980	–	0.954	–	0.978
Fresh weight per plant	60	0.982	–	0.983	–	0.987	–	0.898	–	0.956	–
	75	–	0.991	–	0.992	–	0.976	–	0.949	–	0.972
Dry weight per plant	60	0.996	–	0.983	–	0.981	–	0.904	–	0.982	–
	75	–	0.992	–	0.991	–	0.973	–	0.945	–	0.970

Contd...

	r value
Significant at 5%	0.576
Significant at 1%	0.708

Table 103 (Contd.). Correlation coefficient (r) values for different pairs of characteristics of linseed in Experiment 2

Characteristics	Sampling stages (DAS)	Capsules per plant	Seeds per capsule	1000-seed weight	Seed yield per plant	Biological yield per plant	Harvest index
Height per plant	60	0.980	0.933	0.947	0.969	0.963	0.953
	75	0.973	0.942	0.932	0.960	0.954	0.942
Leaf area per plant	60	0.983	0.885	0.983	0.979	0.971	0.982
	75	0.976	0.851	0.994	0.976	0.967	0.989
Leaf area index	60	0.983	0.884	0.984	0.980	0.972	0.982
	75	0.981	0.874	0.988	0.979	0.971	0.985
Fresh weight per plant	60	0.983	0.917	0.963	0.975	0.968	0.967
	75	0.978	0.858	0.992	0.977	0.968	0.988
Dry weight per plant	60	0.973	0.851	0.991	0.971	0.962	0.991
	75	0.975	0.854	0.992	0.974	0.965	0.990

Contd...

	r value
Significant at 5%	0.576
Significant at 1%	0.708

Table 103 (Contd.). Correlation coefficient (r) values for different pairs of characteristics of linseed in Experiment 2

Characteristics	Sampling stages (DAS)	Oil content	Oil yield per plant	Iodine value	Fibre yield per plant	Lodging
Height per plant	60	0.969	0.973	-0.976	0.899	0.934
	75	0.963	0.965	-0.972	0.888	0.949
Leaf area per plant	60	0.969	0.981	-0.967	0.911	0.874
	75	0.960	0.977	-0.954	0.909	0.833
Leaf area index	60	0.969	0.982	-0.967	0.913	0.871
	75	0.966	0.981	-0.964	0.912	0.860
Fresh weight per plant	60	0.970	0.978	-0.974	0.904	0.914
	75	0.962	0.978	-0.957	0.910	0.842
Dry weight per plant	60	0.955	0.973	-0.951	0.899	0.840
	75	0.959	0.976	-0.954	0.905	0.841

Contd…

	r value
Significant at 5%	0.576
Significant at 1%	0.708

Table 103 (Contd.). Correlation coefficient (r) values for different pairs of characteristics of linseed in Experiment 2

Characteristics	Sampling stages (DAS)	Carbonic anhydrase activity Sampling stages (DAS)		Leaf chlorophyll content Sampling stages (DAS)		Leaf N content Sampling stages (DAS)		Leaf P content Sampling stages (DAS)		Leaf K content Sampling stages (DAS)	
		60	75	60	75	60	75	60	75	60	75
Net photosynthetic rate	60	0.997	–	0.973	–	0.970	–	0.891	–	0.981	–
	75	–	0.999	–	0.980	–	0.961	–	0.926	–	0.960
Carbonic anhydrase activity	60	–	–	0.964	–	0.963	–	0.864	–	0.966	–
	75	–	–	–	0.976	–	0.959	–	0.924	–	0.961
Leaf chlorophyll content	60	–	–	–	–	0.999	–	0.962	–	0.985	–
	75	–	–	–	–	–	0.995	–	0.980	–	0.992
Leaf N content	60	–	–	–	–	–	–	0.957	–	0.978	–
	75	–	–	–	–	–	–	–	0.994	–	0.999
Leaf P content	60	–	–	–	–	–	–	–	–	0.955	–
	75	–	–	–	–	–	–	–	–	–	0.993
Leaf K content	60	–	–	–	–	–	–	–	–	–	–
	75	–	–	–	–	–	–	–	–	–	–

Contd…

	r value
Significant at 5%	0.576
Significant at 1%	0.708

Table 103 (Contd.). Correlation coefficient (r) values for different pairs of characteristics of linseed in Experiment 2

Characteristics	Sampling stages (DAS)	Capsules per plant	Seeds per capsule	1000-seed weight	Seed yield per plant	Biological yield per plant	Harvest index
Net photosynthetic rate	60	0.960	0.820	0.993	0.960	0.949	0.996
	75	0.962	0.852	0.979	0.956	0.945	0.993
Carbonic anhydrase activity	60	0.952	0.825	0.982	0.948	0.936	0.998
	75	0.959	0.862	0.970	0.952	0.940	0.989
Leaf chlorophyll content	60	0.998	0.906	0.979	0.999	0.996	0.950
	75	0.996	0.901	0.983	0.995	0.991	0.962
Leaf N content	60	0.999	0.920	0.973	0.998	0.996	0.947
	75	0.999	0.939	0.960	0.997	0.996	0.931
Leaf P content	60	0.962	0.863	0.928	0.974	0.979	0.850
	75	0.994	0.948	0.935	0.993	0.996	0.889
Leaf K content	60	0.972	0.820	0.996	0.981	0.975	0.964
	75	0.998	0.950	0.951	0.993	0.992	0.927

Contd…

	r value
Significant at 5%	0.576
Significant at 1%	0.708

Table 103 (Contd.). Correlation coefficient (r) values for different pairs of characteristics of linseed in Experiment 2

Characteristics	Sampling stages (DAS)	Oil content	Oil yield per plant	Iodine value	Fibre yield per plant	Lodging
Net photosynthetic rate	60	0.940	0.962	-0.933	0.883	0.813
	75	0.941	0.959	-0.941	0.870	0.860
Carbonic anhydrase activity	60	0.929	0.951	-0.927	0.859	0.835
	75	0.939	0.955	-0.941	0.862	0.877
Leaf chlorophyll content	60	0.993	0.999	-0.988	0.963	0.859
	75	0.988	0.996	-0.984	0.951	0.864
Leaf N content	60	0.995	0.999	-0.992	0.961	0.877
	75	0.998	0.998	-0.997	0.965	0.893
Leaf P content	60	0.972	0.970	-0.957	0.998	0.751
	75	0.999	0.993	-0.998	0.983	0.881
Leaf K content	60	0.962	0.980	-0.949	0.944	0.766
	75	0.996	0.995	-0.998	0.957	0.911

Contd...

	r value
Significant at 5%	*0.576*
Significant at 1%	0.708

Table 103 (Contd.). Correlation coefficient (r) values for different pairs of characteristics of linseed in Experiment 2

Characteristics	Seeds per capsule	1000-seed weight	Seed yield per plant	Biological yield per plant	Harvest index	Oil content	Oil yield per plant	Iodine value	Fibre yield per plant	Lodging
Capsules per plant	0.931	0.964	0.998	0.997	0.934	0.998	0.999	-0.996	0.967	0.883
Seeds per capsule	–	0.964	0.998	0.920	0.784	0.941	0.918	-0.958	0.894	0.969
1000-seed weight	–	–	0.970	0.962	0.983	0.949	0.970	-0.937	0.916	0.771
Seed yield per plant	–	–	–	0.999	0.933	0.997	0.999	-0.992	0.976	0.856
Biological yield per plant	–	–	–	–	0.919	0.998	0.999	-0.993	0.983	0.855
Harvest index	–	–	–	–	–	0.908	0.935	-0.903	0.840	0.795
Oil content	–	–	–	–	–	–	0.997	-0.998	0.979	0.880
Oil yield per plant	–	–	–	–	–	–	–	-0.993	0.973	0.863
Iodine value	–	–	–	–	–	–	–	–	-0.969	-0.907
Fibre yield per plant	–	–	–	–	–	–	–	–	–	0.786

	r value
Significant at 5%	0.576
Significant at 1%	0.708

Table 104. Correlation coefficient (r) values for different pairs of characteristics of linseed in Experiment 3

Characteristics	Sampling stages (DAS)	Leaf area per plant		Leaf area index		Fresh weight per plant		Dry weight per plant		Net photosynthetic rate	
		Sampling stages (DAS)		Sampling stages (DAS)		Sampling stages (DAS)		Sampling stages (DAS)		Sampling stages (DAS)	
		60	75	60	75	60	75	60	75	60	75
Height per plant	60	0.974	–	0.974	–	0.988	–	0.975	–	0.936	–
	75	–	0.957	–	0.957	–	0.964	–	0.951	–	0.670
Leaf area per plant	60	–	–	0.999	–	0.994	–	0.999	–	0.960	–
	75	–	–	–	–	–	0.998	–	0.980	–	0.751
Leaf area index	60	–	–	–	–	0.994	–	0.999	–	0.960	–
	75	–	–	–	–	–	0.998	–	0.980	–	0.751
Fresh weight per plant	60	–	–	–	–	–	–	0.993	–	0.972	–
	75	–	–	–	–	–	–	–	0.991	–	0.707
Dry weight per plant	60	–	–	–	–	–	–	–	–	0.954	–
	75	–	–	–	–	–	–	–	–	–	0.606

Contd…

	r value
Significant at 5%	0.576
Significant at 1%	0.708

Table 104 (Contd.). Correlation coefficient (r) values for different pairs of characteristics of linseed in Experiment 3

Characteristics	Sampling stages (DAS)	Carbonic anhydrase activity		Leaf chlorophyll content		Leaf N content		Leaf P content		Leaf K content		Leaf Ca content	
		Sampling stages (DAS)		Sampling stages (DAS)		Sampling stages (DAS)		Sampling stages (DAS)		Sampling stages (DAS)		Sampling stages (DAS)	
		60	75	60	75	60	75	60	75	60	75	60	75
Height per plant	60	0.985	–	0.973	–	0.974	–	0.999	–	0.981	–	0.968	–
	75	–	0.990	–	0.973	–	0.988	–	0.996	–	0.958	–	0.985
Leaf area per plant	60	0.978	–	0.985	–	0.960	–	0.976	–	0.997	–	0.969	–
	75	–	0.983	–	0.998	–	0.986	–	0.973	–	0.996	–	0.975
Leaf area index	60	0.979	–	0.985	–	0.961	–	0.976	–	0.997	–	0.969	–
	75	–	0.983	–	0.998	–	0.986	–	0.973	–	0.996	–	0.975
Fresh weight per plant	60	0.995	–	0.995	–	0.984	–	0.990	–	0.991	–	0.986	–
	75	–	0.981	–	0.996	–	0.985	–	0.981	–	0.999	–	0.971
Dry weight per plant	60	0.976	–	0.982	–	0.957	–	0.977	–	0.998	–	0.965	–
	75	–	0.957	–	0.977	–	0.962	–	0.975	–	0.994	–	0.940

Contd…

	r value
Significant at 5%	0.576
Significant at 1%	0.708

Table 104 (Contd). Correlation coefficient (r) values for different pairs of characteristics of linseed in Experiment 3

Characteristics	Sampling stages (DAS)	Capsules *per plant*	Seeds *per capsule*	1000-seed *weight*	Seed yield *per plant*	Biological *yield per plant*	Harvest index
Height per plant	60	0.988	0.934	0.972	0.897	0.880	0.877
	75	0.994	0.916	0.954	0.839	0.816	0.942
Leaf area per plant	60	0.975	0.988	0.999	0.968	0.956	0.825
	75	0.983	0.993	0.997	0.944	0.929	0.872
Leaf area index	60	0.975	0.988	0.999	0.967	0.956	0.826
	75	0.983	0.993	0.997	0.944	0.929	0.872
Fresh weight per plant	60	0.993	0.977	0.996	0.935	0.919	0.878
	75	0.987	0.988	0.999	0.949	0.935	0.863
Dry weight per plant	60	0.973	0.985	0.998	0.969	0.958	0.818
	75	0.972	0.971	0.992	0.962	0.952	0.810

Contd...

	r value
Significant at 5%	0.576
Significant at 1%	0.708

Table 104 (Contd.). Correlation coefficient (r) values for different pairs of characteristics of linseed in Experiment 3

Characteristics	Sampling stages (DAS)	Oil content	Oil yield per plant	Iodine value	Fibre yield per plant	Lodging
Height per plant	60	0.761	0.888	-0.996	0.996	-0.667
	75	0.734	0.832	-0.982	0.968	-0.778
Leaf area per plant	60	0.885	0.965	-0.989	0.976	-0.589
	75	0.899	0.944	-0.983	0.957	-0.664
Leaf area index	60	0.886	0.964	-0.989	0.976	-0.590
	75	0.899	0.944	-0.983	0.957	-0.664
Fresh weight per plant	60	0.849	0.931	-0.997	0.983	-0.665
	75	0.879	0.947	-0.992	0.973	-0.645
Dry weight per plant	60	0.879	0.965	-0.990	0.979	-0.578
	75	0.848	0.957	-0.993	0.990	-0.565

Contd...

	r value
Significant at 5%	0.576
Significant at 1%	0.708

Table 104 (Contd.). Correlation coefficient (r) values for different pairs of characteristics of linseed in Experiment 3

Characteristics	Sampling stages (DAS)	Carbonic anhydrase activity		Leaf chlorophyll content		Leaf N content		Leaf P content		Leaf K content		Leaf Ca content	
		Sampling stages (DAS)		Sampling stages (DAS)		Sampling stages (DAS)		Sampling stages (DAS)		Sampling stages (DAS)		Sampling stages (DAS)	
		60	75	60	75	60	75	60	75	60	75	60	75
Net photosynthetic	60	0.982	–	0.991	–	0.984	–	0.942	–	0.939	–	0.993	–
rate	75	–	0.758	–	0.752	–	0.754	–	0.661	–	0.691	–	0.786
Carbonic anhydrase	60	–	–	0.997	–	0.997	–	0.988	–	0.972	–	0.997	–
activity	75	–	–	–	0.993	–	0.999	–	0.990	–	0.975	–	0.998
Leaf chlorophyll	60	–	–	–	–	0.992	–	0.977	–	0.974	–	0.997	–
content	75	–	–	–	–	–	0.995	–	0.984	–	0.993	–	0.987
Leaf N	60	–	–	–	–	–	–	0.978	–	0.951	–	0.998	–
content	75	–	–	–	–	–	–	–	0.991	–	0.980	–	0.997
Leaf P	60	–	–	–	–	–	–	–	–	0.982	–	0.972	–
content	75	–	–	–	–	–	–	–	–	–	0.978	–	0.982
Leaf K	60	–	–	–	–	–	–	–	–	–	–	0.956	–
content	75	–	–	–	–	–	–	–	–	–	–	–	0.964
Leaf Ca	60	–	–	–	–	–	–	–	–	–	–	–	–
content	75	–	–	–	–	–	–	–	–	–	–	–	–

Contd...

	r value
Significant at 5%	0.576
Significant at 1%	0.708

Table 104 (Contd.). Correlation coefficient (r) values for different pairs of characteristics of linseed in Experiment 3

Characteristics	Sampling stages (DAS)	Capsules per plant	Seeds per capsule	1000-seed weight	Seed yield per plant	Biological yield per plant	Harvest index
Net photosynthetic rate	60	0.977	0.973	0.972	0.885	0.863	0.924
	75	0.709	0.755	0.703	0.590	0.563	0.797
Carbonic anhydrase activity	60	0.999	0.962	0.984	0.895	0.875	0.923
	75	0.997	0.955	0.974	0.872	0.849	0.944
Leaf chlorophyll content	60	0.994	0.980	0.992	0.916	0.898	0.907
	75	0.992	0.983	0.994	0.923	0.905	0.900
Leaf N content	60	0.997	0.947	0.969	0.861	0.838	0.950
	75	0.998	0.960	0.979	0.882	0.860	0.936
Leaf P content	60	0.991	0.938	0.975	0.898	0.881	0.883
	75	0.998	0.941	0.975	0.883	0.863	0.915
Leaf K content	60	0.971	0.973	0.992	0.965	0.955	0.807
	75	0.982	0.988	0.999	0.958	0.944	0.848
Leaf Ca content	60	0.995	0.964	0.978	0.882	0.859	0.938
	75	0.992	0.946	0.963	0.850	0.825	0.958

Contd…

	r value
Significant at 5%	0.576
Significant at 1%	0.708

Table 104 (Contd.). Correlation coefficient (r) values for different pairs of characteristics of linseed in Experiment 3

Characteristics	Sampling stages (DAS)	Oil content	Oil yield per plant	Iodine value	Fibre yield per plant	Lodging
Net photosynthetic rate	60	0.882	0.887	-0.956	0.914	-0.763
	75	0.792	0.607	-0.639	0.543	-0.780
Carbonic anhydrase activity	60	0.821	0.891	-0.991	0.971	-0.739
	75	0.815	0.869	-0.981	0.954	-0.778
Leaf chlorophyll content	60	0.865	0.915	-0.986	0.960	-0.717
	75	0.871	0.922	-0.987	0.961	-0.705
Leaf N content	60	0.801	0.858	-0.979	0.953	-0.789
	75	0.824	0.879	-0.984	0.958	-0.765
Leaf P content	60	0.768	0.889	-0.997	0.995	-0.675
	75	0.775	0.876	-0.995	0.984	-0.726
Leaf K content	60	0.854	0.960	-0.992	0.988	-0.561
	75	0.882	0.955	-0.992	0.975	-0.622
Leaf Ca content	60	0.838	0.880	-0.978	0.948	-0.771
	75	0.809	0.848	-0.969	0.936	-0.808

Contd...

	r value
Significant at 5%	0.576
Significant at 1%	0.708

Table 104 (Contd.). Correlation coefficient (r) values for different pairs of characteristics of linseed in Experiment 3

Characteristics	Seeds per capsule	1000-seed weight	Seed yield per plant	Biological yield per plant	Harvest index	Oil content	Oil yield per plant	Iodine value	Fibre yield per plant	Lodging
Capsules per plant	0.955	0.980	0.887	0.867	0.926	0.805	0.883	-0.992	0.974	-0.743
Seeds per capsule	–	0.992	0.968	0.956	0.817	0.942	0.969	-0.961	0.932	-0.593
1000-seed weight	–	–	0.960	0.946	0.846	0.892	0.957	-0.989	0.971	-0.621
Seed yield per plant	–	–	–	0.999	0.663	0.927	0.999	-0.925	0.918	-0.381
Biological yield per plant	–	–	–	–	0.629	0.923	0.998	-0.910	0.906	-0.339
Harvest index	–	–	–	–	–	0.645	0.661	-0.872	0.830	-0.941
Oil content	–	–	–	–	–	–	0.939	-0.814	0.765	-0.426
Oil yield per plant	–	–	–	–	–	–	–	-0.919	0.908	-0.381
Iodine value	–	–	–	–	–	–	–	–	-0.993	0.655
Fibre yield per plant	–	–	–	–	–	–	–	–	–	-0.597

	r value
Significant at 5%	0.576
Significant at 1%	0.708

Table 105. Correlation coefficient (r) values for different pairs of characteristics of linseed in Experiment 4

Characteristics	Sampling stages (DAS)	Leaf area per plant		Leaf area index		Fresh weight per plant		Dry weight per plant		Net photosynthetic rate	
		Sampling stages (DAS)		Sampling stages (DAS)		Sampling stages (DAS)		Sampling stages (DAS)		Sampling stages (DAS)	
		60	75	60	75	60	75	60	75	60	75
Height per plant	60	0.938	–	0.792	–	0.976	–	0.965	–	0.882	–
	75	–	0.947	–	0.948	–	0.933	–	0.989	–	0.969
Leaf area per plant	60	–	–	0.901	–	0.980	–	0.995	–	0.950	–
	75	–	–	–	0.999	–	0.984	–	0.914	–	0.840
Leaf area index	60	–	–	–	–	0.904	–	0.899	–	0.986	–
	75	–	–	–	–	–	0.982	–	0.916	–	0.842
Fresh weight per plant	60	–	–	–	–	–	–	0.994	–	0.962	–
	75	–	–	–	–	–	–	–	0.878	–	0.838
Dry weight per plant	60	–	–	–	–	–	–	–	–	0.955	0.970
	75	–	–	–	–	–	–	–	–	–	–

Contd…

	r value
Significant at 5%	0.576
Significant at 1%	0.708

Table 105 (Contd.). Correlation coefficient (r) values for different pairs of characteristics of linseed in Experiment 4

Characteristics	Sampling stages (DAS)	Carbonic anhydrase activity Sampling stages (DAS)		Leaf chlorophyll content Sampling stages (DAS)		Leaf N content Sampling stages (DAS)		Leaf P content Sampling stages (DAS)		Leaf K content Sampling stages (DAS)		Leaf Mg content Sampling stages (DAS)	
		60	75	60	75	60	75	60	75	60	75	60	75
Height per plant	60	0.958	–	0.961	–	-0.312	–	-0.393	–	-0.396	–	0.772	–
	75	–	0.996	–	0.907	–	-0.025	–	-0.041	–	-0.131	–	0.533
Leaf area per plant	60	0.952	–	0.893	–	-0.049	–	-0.169	–	-0.119	–	0.566	–
	75	–	0.949	–	0.991	–	-0.307	–	-0.326	–	-0.424	–	0.768
Leaf area index	60	0.927	–	0.862	–	0.333	–	0.243	–	0.245	–	0.224	–
	75	–	0.949	–	0.991	–	-0.308	–	-0.327	–	-0.424	–	0.767
Fresh weight per plant	60	0.991	–	0.965	–	-0.101	–	-0.194	–	-0.188	–	0.619	–
	75	–	0.951	–	0.956	–	-0.213	–	-0.236	–	-0.352	–	0.713
Dry weight per plant	60	0.974	–	0.931	–	-0.093	–	-0.201	–	-0.171	–	0.609	–
	75	–	0.972	–	0.881	–	-0.023	–	-0.035	–	-0.107	–	0.497

Contd…

	r value
Significant at 5%	0.576
Significant at 1%	0.708

Table 105 (Contd). Correlation coefficient (r) values for different pairs of characteristics of linseed in Experiment 4

Characteristics	Sampling stages (DAS)	Capsules per plant	Seeds per capsule	1000-seed weight	Seed yield per plant	Biological yield per plant	Harvest index
Height per plant	60	0.938	0.943	0.970	0.932	0.925	0.877
	75	0.956	0.945	0.975	0.963	0.947	0.978
Leaf area per plant	60	0.914	0.901	0.945	0.924	0.901	0.988
	75	0.940	0.947	0.971	0.934	0.928	0.870
Leaf area index	60	0.923	0.901	0.903	0.938	0.925	0.932
	75	0.939	0.945	0.971	0.933	0.926	0.873
Fresh weight per plant	60	0.972	0.967	0.991	0.974	0.963	0.950
	75	0.975	0.983	0.986	0.967	0.969	0.838
Dry weight per plant	60	0.944	0.935	0.971	0.949	0.932	0.972
	75	0.902	0.886	0.932	0.913	0.889	0.994

Contd...

	r value
Significant at 5%	0.576
Significant at 1%	0.708

Table 105 (Contd.). Correlation coefficient (r) values for different pairs of characteristics of linseed in Experiment 4

Characteristics	Sampling stages (DAS)	Oil content	Oil yield per plant	Iodine value	Fibre yield per plant	Lodging
Height per plant	60	0.970	0.933	0.964	0.984	-0.436
	75	0.916	0.962	0.927	0.961	-0.135
Leaf area per plant	60	0.875	0.922	0.947	0.931	-0.128
	75	0.974	0.935	0.959	0.986	-0.443
Leaf area index	60	0.811	0.936	0.725	0.861	0.184
	75	0.972	0.933	0.962	0.985	-0.441
Fresh weight per plant	60	0.954	0.974	0.937	0.985	-0.230
	75	0.999	0.968	0.894	0.996	-0.405
Dry weight per plant	60	0.918	0.948	0.953	0.962	-0.194
	75	0.853	0.911	0.935	0.915	-0.082

Contd...

	r value
Significant at 5%	0.576
Significant at 1%	0.708

Table 105 (Contd.). Correlation coefficient (r) values for different pairs of characteristics of linseed in Experiment 4

Characteristics	Sampling stages (DAS)	Carbonic anhydrase activity		Leaf chlorophyll content		Leaf N content		Leaf P content		Leaf K content		Leaf Mg content	
		Sampling stages (DAS)		Sampling stages (DAS)		Sampling stages (DAS)		Sampling stages (DAS)		Sampling stages (DAS)		Sampling stages (DAS)	
		60	75	60	75	60	75	60	75	60	75	60	75
Net photosynthetic rate	60	0.975	–	0.925	–	0.172	–	0.080	–	0.082	–	0.382	–
	75	–	0.965	–	0.776	–	0.210	–	0.196	–	0.113	–	0.310
Carbonic anhydrase activity	60	–	–	0.984	–	-0.036	–	-0.114	–	-0.133	–	0.563	–
	75	–	–	–	0.902	–	0.002	–	-0.017	–	-0.116	–	0.526
Leaf chlorophyll content	60	–	–	–	–	-0.140	–	-0.192	–	-0.244	–	0.630	–
	75	–	–	–	–	–	-0.430	–	-0.447	–	-0.534	–	0.840
Leaf N content	60	–	–	–	–	–	–	0.986	–	0.993	–	-0.844	–
	75	–	–	–	–	–	–	–	0.999	–	0.984	–	-0.837
Leaf P content	60	–	–	–	–	–	–	–	–	0.976	–	-0.883	–
	75	–	–	–	–	–	–	–	–	–	0.989	–	-0.850
Leaf K content	60	–	–	–	–	–	–	–	–	–	–	-0.885	–
	75	–	–	–	–	–	–	–	–	–	–	–	-0.905
Leaf Mg content	60	–	–	–	–	–	–	–	–	–	–	–	–
	75	–	–	–	–	–	–	–	–	–	–	–	–

	r value
Significant at 5%	0.576
Significant at 1%	0.708

Contd…

Table 105 (Contd.). Correlation coefficient (r) values for different pairs of characteristics of linseed in Experiment 4

Characteristics	Sampling stages (DAS)	Capsules per plant	Seeds per capsule	1000-seed weight	Seed yield per plant	Biological yield per plant	Harvest index
Net photosynthetic	60	0.966	0.950	0.960	0.976	0.964	0.957
rate	75	0.913	0.890	0.916	0.929	0.908	0.985
Carbonic anhydrase	60	0.994	0.990	0.998	0.995	0.990	0.925
activity	75	0.978	0.969	0.988	0.983	0.972	0.961
Leaf chlorophyll	60	0.991	0.996	0.991	0.984	0.988	0.844
content	75	0.885	0.895	0.930	0.876	0.869	0.826
Leaf N	60	-0.010	-0.053	-0.093	0.021	0.013	0.092
content	75	0.008	-0.032	-0.080	0.038	0.033	0.078
Leaf P	60	-0.072	-0.108	-0.166	-0.046	-0.045	-0.036
content	75	-0.015	-0.056	-0.101	0.015	0.009	0.067
Leaf K	60	-0.113	-0.157	-0.189	-0.080	-0.092	0.027
content	75	-0.135	-0.179	-0.213	-0.103	-0.113	-0.002
Leaf Mg	60	0.532	0.562	0.607	0.508	0.508	0.438
content	75	0.540	0.574	0.607	0.513	0.519	0.402

Contd...

	r value
Significant at 5%	0.576
Significant at 1%	0.708

Table 105 (Contd.). Correlation coefficient (r) values for different pairs of characteristics of linseed in Experiment 4

Characteristics	Sampling stages (DAS)	Oil content	Oil yield per plant	Iodine value	Fibre yield per plant	Lodging
Net photosynthetic rate	60	0.888	0.975	0.821	0.931	0.024
	75	0.818	0.926	0.825	0.881	0.112
Carbonic anhydrase activity	60	0.967	0.995	0.886	0.989	-0.198
	75	0.938	0.982	0.903	0.974	-0.138
Leaf chlorophyll content	60	0.995	0.985	0.859	0.993	-0.329
	75	0.945	0.877	0.972	0.954	-0.538
Leaf N content	60	-0.234	0.018	-0.365	-0.179	0.956
	75	-0.212	0.035	-0.376	-0.165	0.935
Leaf P content	60	-0.282	-0.048	-0.476	-0.247	0.918
	75	-0.236	0.012	-0.387	-0.187	0.946
Leaf K content	60	-0.336	-0.084	-0.424	-0.276	0.982
	75	-0.356	-0.107	-0.450	-0.298	0.980
Leaf Mg content	60	0.699	0.510	0.792	0.672	-0.879
	75	0.713	0.516	0.761	0.675	-0.905

Contd...

	r value
Significant at 5%	0.576
Significant at 1%	0.708

Table 105 (Contd.). Correlation coefficient (r) values for different pairs of characteristics of linseed in Experiment 4

Characteristics	Seeds per capsule	1000-seed weight	Seed yield per plant	Biological yield per plant	Harvest index	Oil content	Oil yield per plant	Iodine value	Fibre yield per plant	Lodging
Capsules per plant	0.998	0.993	0.999	0.999	0.885	0.973	0.999	0.839	0.984	-0.197
Seeds per capsule	–	0.992	0.995	0.998	0.864	0.983	0.996	0.838	0.987	-0.245
1000-seed weight	–	–	0.992	0.988	0.909	0.980	0.992	0.897	0.996	-0.256
Seed yield per plant	–	–	–	0.998	0.901	0.963	0.999	0.838	0.979	-0.161
Biological yield per plant	–	–	–	–	0.874	0.969	0.999	0.818	0.977	-0.181
Harvest index	–	–	–	–	–	0.813	0.898	0.894	0.882	0.024
Oil content	–	–	–	–	–	–	0.965	0.872	0.991	-0.419
Oil yield per plant	–	–	–	–	–	–	–	0.838	0.980	-0.165
Iodine value	–	–	–	–	–	–	–	–	0.911	-0.412
Fibre yield per plant	–	–	–	–	–	–	–	–	–	-0.341

	r value
Significant at 5%	0.576
Significant at 1%	0.708

Table 106. Correlation coefficient (r) values for different pairs of characteristics of linseed in Experiment 5

Characteristics	Sampling stages (DAS)	Leaf area per plant Sampling stages (DAS)		Leaf area index Sampling stages (DAS)		Fresh weight per plant Sampling stages (DAS)		Dry weight per plant Sampling stages (DAS)		Net photosynthetic rate Sampling stages (DAS)	
		60	75	60	75	60	75	60	75	60	75
Height per plant	60	0.975	–	0.975	–	0.997	–	0.985	–	0.509	–
	75	–	0.990	–	0.990	–	0.981	–	0.967	–	0.483
Leaf area per plant	60	–	–	–	–	0.979	–	0.997	–	0.450	–
	75	–	–	–	0.999	–	0.980	–	0.934	–	0.490
Leaf area index	60	–	–	–	–	0.980	–	0.998	–	0.449	–
	75	–	–	–	–	–	0.980	–	0.934	–	0.491
Fresh weight per plant	60	–	–	–	–	–	–	0.985	–	0.561	–
	75	–	–	–	–	–	–	–	0.974	–	0.639
Dry weight per plant	60	–	–	–	–	–	–	–	–	0.432	–
	75	–	–	–	–	–	–	–	–	–	0.618

Contd…

	r value
Significant at 5%	0.576
Significant at 1%	0.708

Table 106 (Contd.). Correlation coefficient (r) values for different pairs of characteristics of linseed in Experiment 5

Characteristics	Sampling stages (DAS)	Carbonic anhydrase activity		Leaf chlorophyll content		Leaf N content		Leaf P content		Leaf K content		Leaf Ca content		Leaf Mg content	
		Sampling stages (DAS)		Sampling stages (DAS)		Sampling stages (DAS)		Sampling stages (DAS)		Sampling stages (DAS)		Sampling stages (DAS)		Sampling stages (DAS)	
		60	75	60	75	60	75	60	75	60	75	60	75	60	75
Height per plant	60	0.766	–	0.559	–	0.901	–	0.820	–	0.837	–	0.673	–	0.052	–
	75	–	0.757	–	0.558	–	0.730	–	0.811	–	0.728	–	0.796	–	-0.257
Leaf area per plant	60	0.730	–	0.515	–	0.832	–	0.764	–	0.798	–	0.779	–	-0.051	–
	75	–	0.766	–	0.569	–	0.629	–	0.722	–	0.643	–	0.798	–	-0.241
Leaf area index	60	0.729	–	0.515	–	0.834	–	0.765	–	0.800	–	0.779	–	-0.051	–
	75	–	0.767	–	0.570	–	0.628	–	0.722	–	0.643	–	0.797	–	-0.239
Fresh weight per plant	60	0.807	–	0.612	–	0.863	–	0.772	–	0.792	–	0.654	–	0.100	–
	75	–	0.868	–	0.706	–	0.659	–	0.754	–	0.608	–	0.674	–	-0.069
Dry weight per plant	60	0.715	–	0.495	–	0.870	–	0.805	–	0.834	–	0.775	–	-0.061	–
	75	–	0.836	–	0.676	–	0.804	–	0.876	–	0.723	–	0.644	–	-0.082

Contd...

	r value
Significant at 5%	0.576
Significant at 1%	0.708

Table 106 (Contd). Correlation coefficient (r) values for different pairs of characteristics of linseed in Experiment 5

Characteristics	Sampling stages (DAS)	Capsules per plant	Seeds per capsule	1000-seed weight	Seed yield per plant	Biological yield per plant	Harvest index
Height per plant	60	0.901	0.950	0.968	0.972	0.975	0.907
	75	0.917	0.853	0.985	0.914	0.916	0.891
Leaf area per plant	60	0.925	0.863	0.989	0.923	0.924	0.901
	75	0.928	0.789	0.980	0.875	0.874	0.887
Leaf area index	60	0.925	0.864	0.989	0.924	0.925	0.901
	75	0.929	0.790	0.981	0.875	0.874	0.888
Fresh weight per plant	60	0.933	0.947	0.983	0.980	0.981	0.937
	75	0.977	0.875	0.999	0.946	0.944	0.959
Dry weight per plant	60	0.907	0.884	0.981	0.931	0.934	0.890
	75	0.932	0.957	0.978	0.986	0.988	0.942

Contd...

	r value
Significant at 5%	0.576
Significant at 1%	0.708

Table 106 (Contd.). Correlation coefficient (r) values for different pairs of characteristics of linseed in Experiment 5

Characteristics	Sampling stages (DAS)	Oil content	Oil yield per plant	Iodine value	Fibre yield per plant	Lodging
Height per plant	60	0.532	0.950	0.791	0.846	-0.982
	75	0.469	0.885	0.642	0.835	-0.968
Leaf area per plant	60	0.490	0.895	0.658	0.847	-0.966
	75	0.477	0.846	0.568	0.843	-0.925
Leaf area index	60	0.490	0.896	0.659	0.847	-0.967
	75	0.478	0.847	0.568	0.843	-0.925
Fresh weight per plant	60	0.587	0.962	0.796	0.885	-0.967
	75	0.627	0.931	0.709	0.925	-0.920
Dry weight per plant	60	0.468	0.902	0.682	0.829	-0.982
	75	0.605	0.971	0.817	0.891	-0.961

Contd…

	r value
Significant at 5%	0.576
Significant at 1%	0.708

Table 106 (Contd.). Correlation coefficient (r) values for different pairs of characteristics of linseed in Experiment 5

Characteristics	Sampling stages (DAS)	Carbonic anhydrase activity		Leaf chlorophyll content		Leaf N content		Leaf P content		Leaf K content		Leaf Ca content		Leaf Mg content	
		Sampling stages (DAS)		Sampling stages (DAS)		Sampling stages (DAS)		Sampling stages (DAS)		Sampling stages (DAS)		Sampling stages (DAS)		Sampling stages (DAS)	
		60	75	60	75	60	75	60	75	60	75	60	75	60	75
Net photosynthetic rate	60	0.939	–	0.996	–	0.183	–	-0.009	–	-0.011	–	-0.184	–	0.864	–
	75	–	0.936	–	0.995	–	0.214	–	0.308	–	-0.044	–	-0.134	–	0.722
Carbonic anhydrase activity	60	–	–	0.961	–	0.462	–	0.289	–	0.300	–	0.159	–	0.642	–
	75	–	–	–	0.964	–	0.417	–	0.524	–	0.232	–	0.224	–	0.435
Leaf chlorophyll content	60	–	–	–	–	0.219	–	0.029	–	0.034	–	-0.101	–	0.817	–
	75	–	–	–	–	–	0.251	–	0.351	–	0.012	–	-0.041	–	0.658
Leaf N content	60	–	–	–	–	–	–	0.981	–	0.977	–	0.681	–	-0.198	–
	75	–	–	–	–	–	–	–	0.991	–	0.946	–	0.591	–	-0.344
Leaf P content	60	–	–	–	–	–	–	–	–	0.997	–	0.736	–	-0.374	–
	75	–	–	–	–	–	–	–	–	–	0.931	–	0.631	–	-0.304
Leaf K content	60	–	–	–	–	–	–	–	–	–	–	0.788	–	-0.403	–
	75	–	–	–	–	–	–	–	–	–	–	–	0.782	–	-0.626
Leaf Ca content	60	–	–	–	–	–	–	–	–	–	–	–	–	-0.654	–
	75	–	–	–	–	–	–	–	–	–	–	–	–	–	-0.776
Leaf Mg content	60	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	75	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Contd…

	r value
Significant at 5%	0.576
Significant at 1%	0.708

Table 106 (Contd.). Correlation coefficient (r) values for different pairs of characteristics of linseed in Experiment 5

Characteristics	Sampling stages (DAS)	Capsules per plant	Seeds per capsule	1000-seed weight	Seed yield per plant	Biological yield per plant	Harvest index
Net photosynthetic rate	60	0.731	0.655	0.575	0.692	0.678	0.791
	75	0.779	0.667	0.626	0.717	0.703	0.828
Carbonic anhydrase activity	60	0.916	0.835	0.821	0.886	0.876	0.953
	75	0.950	0.814	0.859	0.885	0.875	0.970
Leaf chlorophyll content	60	0.786	0.679	0.636	0.728	0.715	0.835
	75	0.834	0.701	0.693	0.762	0.748	0.873
Leaf N content	60	0.623	0.862	0.773	0.819	0.831	0.644
	75	0.536	0.865	0.679	0.787	0.800	0.585
Leaf P content	60	0.496	0.749	0.680	0.699	0.714	0.505
	75	0.644	0.914	0.772	0.858	0.870	0.685
Leaf K content	60	0.531	0.743	0.713	0.709	0.723	0.529
	75	0.438	0.713	0.630	0.655	0.671	0.448
Leaf Ca content	60	0.536	0.417	0.690	0.492	0.499	0.449
	75	0.516	0.453	0.685	0.510	0.519	0.439
Leaf Mg content	60	0.288	0.298	0.090	0.285	0.272	0.380
	75	0.136	0.059	-0.087	0.068	0.051	0.210

Contd...

	r value
Significant at 5%	0.576
Significant at 1%	0.708

Table 106 (Contd.). Correlation coefficient (r) values for different pairs of characteristics of linseed in Experiment 5

Characteristics	Sampling stages (DAS)	Oil content	Oil yield per plant	Iodine value	Fibre yield per plant	Lodging
Net photosynthetic rate	60	0.997	0.747	0.794	0.847	-0.336
	75	0.999	0.769	0.780	0.882	-0.377
Carbonic anhydrase activity	60	0.952	0.917	0.863	0.974	-0.630
	75	0.930	0.912	0.808	0.992	-0.654
Leaf chlorophyll content	60	0.999	0.779	0.790	0.888	-0.391
	75	0.994	0.808	0.782	0.922	-0.446
Leaf N content	60	0.187	0.777	0.687	0.542	-0.947
	75	0.200	0.753	0.748	0.483	-0.876
Leaf P content	60	-0.004	0.646	0.541	0.390	-0.900
	75	0.293	0.827	0.785	0.591	-0.928
Leaf K content	60	0.002	0.653	0.516	0.416	-0.919
	75	-0.060	0.599	0.508	0.330	-0.870
Leaf Ca content	60	-0.125	0.426	0.085	0.368	-0.775
	75	-0.149	0.442	0.125	0.348	-0.803
Leaf Mg content	60	0.830	0.362	0.576	0.463	0.133
	75	0.733	0.148	0.350	0.315	0.350

Contd...

	r value
Significant at 5%	0.576
Significant at 1%	0.708

Table 106 (Contd.). Correlation coefficient (r) values for different pairs of characteristics of linseed in Experiment 5

Characteristics	Seeds per capsule	1000-seed weight	Seed yield per plant	Biological yield per plant	Harvest index	Oil content	Oil yield per plant	Iodine value	Fibre yield per plant	Lodging
Capsules per plant	0.847	0.971	0.932	0.925	0.990	0.770	0.933	0.735	0.982	-0.823
Seeds per capsule	–	0.882	0.982	0.985	0.897	0.655	0.979	0.941	0.846	-0.895
1000-seed weight	–	–	0.950	0.948	0.955	0.614	0.934	0.714	0.917	-0.931
Seed yield per plant	–	–	–	0.999	0.960	0.706	0.997	0.896	0.921	-0.911
Biological yield per plant	–	–	–	–	0.954	0.692	0.995	0.895	0.912	-0.917
Harvest index	–	–	–	–	–	0.819	0.968	0.821	0.992	-0.817
Oil content	–	–	–	–	–	–	0.759	0.773	0.875	-0.362
Oil yield per plant	–	–	–	–	–	–	–	0.917	0.937	-0.874
Iodine value	–	–	–	–	–	–	–	–	0.797	-0.692
Fibre yield per plant	–	–	–	–	–	–	–	–	–	-0.738

	r value
Significant at 5%	0.576
Significant at 1%	0.708

5.1.2 Cultivar differences

The perusal of the data of Experiments 1-5 (Tables 8-12, 26-30, 44-48, 63-77 and 82-86) reveals that the linseed cultivars differ with each other with regard to growth parameters studied at 60 and 75 DAS. Cultivar Shubhra gives the maximum value for these parameters in all five experiments. On the other hand, Laxmi 27 (also Rashmi for some parameters) in Experiment 1 and Parvati in Experiments 2-5 exhibit the minimum value for growth parameters studied (Tables 8-12, 26-30, 44-48, 63-77 and 82-86). These differences in cultivars in respect of growth parameters may be ascribed to the variation in genes of cultivars. These results broadly corroborate those of Dixit *et al.* (1994), Khare *et al.* (1995), Samui *et al.* (1995), Sharma *et al.* (1997), Singh and Verma (1999), Dubey (2001), Kumar and Badiyala (2001) and Gontia and Sonakia (2002) on linseed.

5.2 Physiological and biochemical parameters

5.2.1 Effect of treatments

A substantial increase in P_N, CA activity and chlorophyll content due to GA_3 treatment over the water-treated control in Experiment 1 (Tables 13-15) is worth mentioning. The enhancing effect of GA_3 on CA activity may be attributed to the hormone-induced increase in transcription and/or translation of the gene that codes for CA (Okabe *et al.*, 1980, 1984; Sugiharto *et al.*, 1992). The improvement in chlorophyll content in treated plants can be attributed to its roles in various metabolic processes related to chlorophyll synthesis. These results are in accord with the findings of Saran *et al.* (1992), Khan (1996), Hayat *et al.* (2001), Khan and Samiullah (2003) and Afroz *et al.* (2005) on mustard.

The improvement in P_N, CA activity and chlorophyll content in plants treated with basal N and P (Tables 31-33; Experiment 2) and foliar Ca and/or Mg treatments (Tables 49-51, 68-70, 87-89; Experiments 3-5), along with a uniform GA_3 treatment, over no-nutrient control is not far to seek. The beneficial effect of these nutrients may be attributed to their various roles mentioned earlier (pp. 87 and 88) being responsible directly or indirectly for the higher values for these parameters. These findings agree with those of Terry and Ulrich (1974), Kirkby and Pilbeam (1984), Khan *et al.* (1996), Mohammad *et al.* (1997), Sun and Payn (1999), Bose and Mishra (2001), Shaul (2002), Courtois *et al.* (2003) and Mohammad (2004) on plants other than linseed. The enhanced activity of CA may have led to increased P_N conceivably through a rapid reversible hydration of carbon dioxide maintaining its constant supply to ribulose bisphosphate carboxylase oxygenase in the stroma of the chloroplast. Such a relationship between CA and P_N has also been reported by Ohki (1978), Khan (1994) and Afroz *et al.* (2005). Moreover, many compounds involved in photosynthesis, being themselves nitrogenous and phosphatic in nature or becoming active in the presence of Ca and Mg would naturally depend upon these essential nutrient elements for their production or activation (Marschner, 2002). Thus, these factors may be helpful in enhancing P_N of nutrient treated plants. Also, a significant improvement in chlorophyll content may have direct impact on P_N. A contribution of CA and chlorophyll content to P_N is also borne out from the correlation studies in which these parameters have been noted to be strongly and positively correlated with P_N (Tables 102-106).

The enhancement in leaf N and P content due to basal N and P combinations in Experiment 2 (Tables 34 and 35), leaf N and Ca content due to Ca spray in Experiment 3 (Tables 52 and 55), leaf Mg content due to Mg spray in Experiment 4 (Table 74) and leaf P, K, Ca and Mg content due to Ca and Mg spray in Experiment 5 (Tables 91-94) over the respective no-nutrient control is understandable and may be ascribed to their ready availability in the soil and foliage and impact of one nutrient on the absorption of the other as already mentioned on pages 10-13.

A decrease in leaf K and Ca content due to Mg spray and in leaf Mg content due to Ca application in Experiment 4 (Table 74) and in Experiment 5 (Table 94) can be attributed to their mutual antagonistic effect. These results agree with the findings of Stein, 1990 and Hille, 1992 on other plants. As nutrients play important roles in plants (pp. 87 and 88), their enhanced contents in plants may directly or indirectly help in the accumulation of dry matter of treated plants. The correlation studies also reveal a positive and significant correlation between these nutrients and dry matter of plants (Tables 102-106). These results corroborate the findings of Kirkby and Pilbeam (1984), Wilkinson and Duncan (1993), Chaubey and Dwivedi (1995), Xiong and Zhou (1995), Sharma *et al.* (1996), Sarode *et al.* (1997, 1998) and Courtois *et al.* (2003) on various plants including linseed.

5.2.2 Cultivar differences

As noted for growth parameters (Tables 8-12, 26-30, 44-48, 63-77 and 82-86), cultivar Shubhra gave the maximum value for most of the physiological and biochemical parameters, including P_N, chlorophyll content and CA activity at one or other stage of growth in Experiments 1-5 (Tables 13-18, 31-36, 49-55, 68-74 and 87-94). On the other hand, Laxmi 27 (also Rashmi for several parameters) in Experiment 1 and Parvati (also Shekhar for a few parameters in the remaining Experiments) showed the minimum value for most of these parameters (Tables 13-18, 31-36, 49-55, 68-74 and 87-94). These variations in cultivars in the various experiments can also be attributed to the variation in the genetic material of cultivars. These results broadly resemble the findings of Siddiqui (1999) and Kumar and Badiyala (2001) on linseed.

5.3 Yield and quality characteristics

5.3.1 Effect of treatments

The improvement in the number of capsules per plant resulting from the application of pre-sowing seed as well as foliar treatment with GA_3 in Experiment 1 (Table 19); of the combinations of N and P in the presence of a uniform dose of K in Experiment 2 (Table 37); and of the spray of Ca and/or Mg in Experiments 3-5 (Tables 56, 75 and 95) as also in the number of seeds per capsule due to spray of Mg in Experiment 4 (Table 75) over the respective controls is a noteworthy observation.

The increase in capsule number due to GA_3 treatment (Table 19) may be traced to its various roles, particularly in differentiation (Huttly and Phillips, 1995; Mobin, 1999; Afroz *et al.*, 2005) leading to enhanced number of flowers which develop into fruits; cell division and cell enlargement (Liu and Loy, 1976; Moore, 1989; Huttly and Phillips, 1995; Arteca, 1996; Marschner, 2002) resulting in desired development of under-developed capsules especially at the terminal end of branches; promotion of P_N (Afroz *et al.*, 2005) providing sufficient C skeleton; and membrane permeability (Wood and Paleg, 1972; Crozier and Turnbull, 1984) facilitating partitioning. These results are in agreement with the findings of Singh and Kumar (1991), Khan (1996), Khan *et al.* (1996, 2002), Khan and Samiullah (2003) and Afroz *et al.* (2005) on mustard.

The increase in capsule number per plant as a result of N and P treatment (Table 37) can be ascribed to their roles in growth in general and differentiation in particular (Marschner, 2002). Moreover, as revealed by the data of leaf analysis, the absorption of these nutrients increases in treated plants probably due to their ready availability from the soil and positive effect on root development (Tables 34 and 35). The better nutrient status may lead to increased assimilation as is borne out by the data for P_N (Table 31) and translocation of photosynthates and, naturally, this is manifested in the improvement in growth and yield characteristics (Patidar *et al.*, 2000) hence higher value for capsules per plant in treated plants. These findings resemble those of other workers, including Dwivedi and Chaubey (1995), Samui *et al.*, (1995), Khare *et al.* (1996), Singh and Verma (1997), Mohammad and Siddiqui (1999), Singh *et al.* (2000), Bastia and Mohanty (2001), Dubey (2001), Kumar *et al.* (2002) and Badiyala and Kumar (2003) on linseed.

The enhancement in the number of capsules per plant caused by the application of spray Ca and/or Mg (Tables 56, 75 and 95) may be attributed to their roles leading directly or indirectly to growth and differentiation (Hewitt, 1963; Xiong and Zhou, 1995; Marschner, 2002). These results corroborate the findings of Khan *et al.* (2001), Shanker *et al.* (2001) and Sarkar *et al.* (2007) on plants other than linseed. The observed improvement in 1000-seed weight resulting from the application of basal N and P in Experiment 2 (Table 38), of Ca spray in Experiment 3 (Table 57) and of Ca plus Mg spray in Experiment 5 (Table 96) over the respective no-nutrient controls is not hard to explain. N and Ca, by virtue of their direct or indirect roles in protein synthesis, can be helpful in increasing the content of proteins in seeds of treated plants, hence the higher value for 1000-seed weight. Similar beneficial effects of these nutrients on 1000-seed weight has also been noted by Dixit *et al.* (1994) on linseed and Afroz *et al*, (2005) on mustard.

The enhanced yield attributing parameters of treated plants, particularly capsules per plant, is likely to have contributed to the increased seed yield. This proposition is confirmed by correlation studies also wherein various yield parameters may be noted to be positively and significantly correlated with seed yield (Tables 102-106). The increased seed yield of treated plants seems to be mainly responsible for the observed high oil yield as there is no effect of the treatments on oil content of seeds (Tables 22, 40, 59, 78 and 98). The non-significant effect of various treatments on iodine value in Experiments 1-5 (Tables 23, 41, 60, 79 and 99) suggests that these parameters may be governed by the genetic make up and not by the treatments.

The observed increase in the fibre yield of treated plants (Tables 24, 42, 61, 80 and 100) is not surprising. As noted earlier, the various treatments improved plant dry weight which may be helpful in increasing the fibre yield. The comparatively lesser increase in fibre yield of plants receiving GA_3 treatment only in Experiment 1 (Table 24) and higher increase due to nutrients particularly Ca and Mg in combination with

GA_3 treatment, (Tables 42, 61, 80 and 100) is on expected lines. In contrast to GA_3, these two nutrients happen to be structural component of plant cells and are involved in the formation of middle lamellae in the form of their pectates. It is noteworthy that correlation studies also show a positive relationship between dry matter and fibre yield (Tables 102-106). The decrease in lodging due to nutrients, particularly Ca and/or Mg spray, in Experiments 3-5 (Tables 62, 81 and 101) may be attributed to the increased fibre yield in the nutrient treated plants. This proposition is supported by correlation studies wherein an inverse relationship has been noted between lodging and fibre yield (Tables 102-106).

5.3.2 Cultivar differences

Cultivar Shubhra gave the maximum value for most of the yield parameters in all experiments (Tables 19-25, 37-43, 56-62, 75-81 and 95-101). On the other hand, cultivar Rashmi (also Laxmi 27 for several parameters) in Experiment 1 and Parvati (also Shekhar for some parameters) in Experiments 2-5 registered the minimum value for these parameters (Tables 19-25, 37-43, 56-62, 75-81 and 95-101). The differences in cultivars in respect of yield parameters may again be ascribed to the variation in the genetic make up of the cultivars. These results broadly corroborate the findings of Dixit *et al.* (1994), Khare *et al.* (1995), Sharma *et al.* (1997), Mohammad and Siddiqui (1999), Bastia and Mohanty (2001), Bhateria *et al.* (2001), Dubey (2001), Kumar and Badiyala (2001) and Gontia and Sonakia (2002) on linseed. The narrow differences in cultivars with regard to iodine value in Experiments 2-4 (Tables 41, 60 and 79) suggest that the genetic constitution of the cultivars does not vary to the extent that affect iodine value considerably.

Summary

Chapter 6

SUMMARY

The present thesis comprises six chapters. In Chapter 1 (Introduction), the importance of the problem "Response of *Linum usitatissimum* L. to the application of GA_3, N, P, Ca and Mg" has been discussed briefly. In view of the lacunae in the understanding of the problem, justifications have been put forward for undertaking the present work. Moreover, the logical basis of each of the five experiments undertaken has been mentioned briefly.

In Chapter 2 (Review of Literature), publications pertaining to general aspects of linseed, gibberellins and inorganic mineral nutrition, and to the physiological roles of N, P, K, Ca and Mg as well as to the effect of their application on linseed have been reviewed with special reference to the work done in India.

In Chapter 3 (Materials and Methods), details of the techniques and methodologies employed for conducting the five experiments have been given.

Chapter 4 (Experimental Results) includes the detailed data regarding the crop response based on growth characteristics, physiological and biochemical parameters and yield and quality characteristics. These were mostly found significant on statistical analysis at $p>0.05$. The data of the five factorial randomized experiments, each conducted during 'rabi' (winter) season, are summarized below.

Experiment 1 was conducted during the winter season of 2003-2004 to test the efficacy of GA_3 spray on five newly released cultivars of linseed (*Linum usitatissimum* L.), namely Laxmi 27, Parvati, Rashmi, Shekhar and Shubhra. There were three GA_3 doses (0, 10^{-8} and 10^{-6}M), with each treatment consisting of pre-sowing seed immersion followed by foliar spray at 40 DAS on plants raised from the treated seeds. The plants were grown with a uniform officially recommended dose of 90 kg N, 30 kg P and 30 kg K/ha, i.e. 40.2 mg N, 13.4 mg P and 13.4 mg K/kg soil. The performance of the crop was assessed in terms of growth characteristics, namely height per plant, leaf area per plant, leaf area index, fresh weight per plant and dry weight per plant, and physiological and biochemical parameters, viz. P_N, CA activity, leaf chlorophyll content and leaf N, P and K content studied at 60 and 75 DAS and yield and quality characteristics (capsules per plant, seeds per capsule, 1000-seed weight, seed yield per plant, biological yield per plant, harvest index, oil content of seeds, oil yield per plant, iodine value, fibre yield per plant and lodging) at harvest. The data revealed that

(i) Pre-sowing seed and foliar treatment of GA_3 at 10^{-6}M proved best for most of the parameters studied. This treatment enhanced, for example, dry weight per plant by 40.5% and P_N by 12.2% at 75 DAS and seed yield per plant by 24.7%, oil yield per plant by 27.1% and fibre yield per plant by 55.9% at harvest over 0 M GA_3 (control). Moreover, 10^{-6}M GA_3 increased lodging by 43.7% compared with the control.

(ii) Regarding cultivars, Shubhra performed best. It was followed by Parvati and Shekhar with regard to some parameters, including seed yield per plant and oil yield per plant. The performance of Shubhra surpassed that of Laxmi 27 which gave the minimum values with regard to dry weight per plant by 65.2% and P_N by 13.8% at 75 DAS and seed yield per plant by 15.8%, oil yield per plant by 17.9% and fibre yield per plant by 35.5% at harvest.

(iii) The interaction 10^{-6}M GA_3 x Shubhra gave the maximum values for most of the parameters. For instance, this interaction increased dry weight per plant by 131.6% and P_N by 27.2% at 75 DAS and seed yield per plant by 44.8%, oil yield per plant by 49.7% and fibre yield per plant by 105.8% at harvest over 0 M GA_3 x Laxmi 27 which gave the lowest values. Moreover, 10^{-6}M GA_3 x Shubhra increased lodging by 67.4% compared with 0 M GA_3 x Laxmi 27.

Experiment 2 was performed during the winter season of 2004-2005 on three better performing cultivars, viz. Parvati, Shekhar and Shubhra selected on the basis of the data of Experiment 1. Four graded levels of N and P, i.e. 0 kg N + 0 kg P/ha (N_0P_0), $N_{30}P_{10}$, $N_{60}P_{20}$ and $N_{90}P_{30}$ were applied to test if combination (s) of basal N and P other than the one applied in Experiment 1 could improve the performance of these cultivars grown with a uniform basal dose of 30 kg K/ha and treated with the best pre-sowing seed and foliar spray dose of 10^{-6}M GA_3 emerging in Experiment 1. The important results of this experiment are summarized below.

(i) Treatment $N_{60}P_{20}$ proved best for most parameters studied. This treatment increased, for example, dry weight per plant by 51.5% and P_N by 10.9% at 75 DAS and seed yield per plant by 83.3%, oil yield per plant by 97.3% and fibre yield per plant by 78.7% at harvest compared with N_0P_0 (control).

(ii) Of the three cultivars, Shubhra again proved best. It enhanced dry weight per plant by 17.1% and P_N by 10.7% at 75 DAS and seed yield per plant by 10.5%, oil yield per plant by 14.8% and fibre yield per plant by 10.5% at harvest compared with Parvati which gave the lowest values.

(iii) The interaction $N_{60}P_{20}$ x Shubhra gave the maximum values for most parameters. This interaction increased, for instance, dry weight per plant by 73.1% and P_N by 23.6% at 75 DAS and seed yield per plant by 104.8%, oil yield per plant by 130.3% and fibre yield per plant by 86.8% at harvest over N_0P_0 x Parvati which gave the minimum values. Moreover, $N_{60}P_{20}$ x Shubhra enhanced lodging by 3.4% compared with N_0P_0 x Parvati.

Experiment 3 was conducted on the same three cultivars of linseed (Parvati, Shekhar and Shubhra) during the winter season of 2005-2006. This experiment was performed to test whether foliar spray of Ca could enhance the performance of these cultivars. Four doses of Ca, viz. 0 kg Ca/ha (Ca_0), Ca_1, Ca_2 and Ca_3 were applied at 40 DAS. The cultivars were grown with the pre-sowing seed as well as spray treatment of 10^{-6} M GA_3 and the basal dose of N and P (with K_{30}). i.e. $N_{60}P_{20}K_{30}$, that had proved best in Experiment 1 and Experiment 2 respectively. The important findings are given below.

(i) Spray treatment of Ca at 2 kg/ha (Ca_2) proved best for most of the parameters. For example, this treatment increased, dry weight per plant by 34.3% and leaf Ca content by 61.1% at 75 DAS and seed yield per plant by 69.9%, oil yield per plant by 74.9% and fibre yield per plant by 85.7% at harvest over Ca_0 (control). Moreover, it reduced lodging of the crop by 4.9% compared with the control.

(ii) Cultivar Shubhra continued to maintain its superiority with regard to most of the parameters studied. For example, dry weight per plant increased by 33.1% at 75 DAS and seed yield per plant by 14.5%, oil yield per plant by 15.5% and fibre yield per plant by 4.3% at harvest compared with Parvati which gave the minimum values.

(iii) The interaction Ca_2 x Shubhra proved best for most of the parameters. This interaction enhanced, for example, dry weight per plant by 78.2% at 75 DAS and seed yield per plant by 91.9%, oil yield per plant by 90.1% and fibre yield per plant by 90.2% at harvest over Ca_0 x Parvati which gave the minimum value. Moreover, Ca_2 x Shubhra decreased lodging of the plants by 19.0% compared with Ca_1 x Parvati (which was at par with Ca_0 x Parvati in its effect) and gave the maximum value for lodging.

Experiment 4 was carried out simultaneously with Experiment 3 on the same three better performing cultivars of linseed to test the efficacy of Mg spray. Four doses of Mg, viz. 0 kg Mg/ha (Mg_0), $Mg_{0.5}$, $Mg_{1.0}$ and $Mg_{1.5}$ were sprayed at 40 DAS on plants grown with 10^{-6}M GA_3 and basal nutrient dose $N_{60}P_{20}K_{30}$. The important results are summarized below.

(i) Foliar spray treatment $Mg_{0.5}$ proved best for most of the parameters. For example, it enhanced dry matter by 25.8%, P_N by 17.4%, leaf chlorophyll content by 17.3% and leaf Mg content by 11.7% at 75 DAS and seed yield per plant by 24.8%, oil yield per plant by 27.4% and fibre yield per plant by 21.6% at harvest over Mg_0 (control). Moreover, $Mg_{0.5}$ decreased lodging of the plant by 1.9% compared with the control.

(ii) Among cultivars, Shubhra again performed best for most of the parameters studied. It increased, for instance, dry weight per plant by 56.0%, P_N by 13.3% leaf chlorophyll content by 8.1% and leaf Mg content by 15.7% at 75 DAS and seed yield per plant by 19.1%, oil yield per plant by 27.6% and fibre yield per plant by 11.2% at harvest compared with Parvati which gave the lowest values.

(iii) The interaction, $Mg_{0.5}$ x Shubhra proved best and improved dry weight per plant by 86.4%, P_N by 29.5% and leaf chlorophyll content by 27.2% at 75 DAS and seed yield per plant by 48.3%, oil yield per plant by 63.0% and fibre yield per plant by 35.6% at harvest over Mg_0 x Parvati which gave the lowest values. Moreover, $Mg_{0.5}$ x Shubhra decreased lodging by 14.4% compared with Mg_0 x Parvati which gave the maximum value for lodging.

Experiment 5 was conducted on Parvati, Shekhar and Shubhra during the winter season of 2006-2007 to test if spray dose of Ca (Ca_2) and Mg ($Mg_{0.5}$), emanating as the best treatments in Experiments 3 and 4 respectively, could increase their efficacy further. The same three cultivars were grown with the pre-sowing seed treatment as well as spray of 10^{-6}M GA_3 and the basal nutrient dose ($N_{60}P_{20}K_{30}$) that proved best in Experiments 1 and 2 respectively. The crop received four combinations of foliar spray of Ca and Mg, viz. 0 kg Ca + 0 kg Mg (Ca_0Mg_0), Ca_2Mg_0, $Ca_0Mg_{0.5}$ and $Ca_2Mg_{0.5}$, at 40 DAS. The results are summarized below.

(i) The combined Ca and Mg ($Ca_2Mg_{0.5}$) proved more efficacious than Ca or Mg alone for most of the parameters. This treatment improved dry weight per plant by 20.6%, P_N by 19.1% and leaf chlorophyll content by 25.7% at 75 DAS and seed yield per plant by 39.6%, oil yield per plant by 46.9% and fibre yield per plant by 36.9% at harvest over Ca_0Mg_0 (control). Moreover, $Ca_2Mg_{0.5}$ decreased lodging of plants by 13.9% compared with the control (Ca_0Mg_0) and by 4.0% and 12.5% compared with Ca_2Mg_0 and $Ca_0Mg_{0.5}$ respectively.

(ii) Cultivar Shubhra maintained its superiority in this experiment also. For example, its dry weight per plant was higher by 19.3%, P_N by 5.8% and leaf chlorophyll content by 3.3 % at 75 DAS and seed yield per plant by 14.1%, oil yield per plant by 19.8 % and fibre yield per plant by 6.2% at harvest compared with Parvati which gave the lowest values.

(iii) Interaction $Ca_2Mg_{0.5}$ x Shubhra gave the maximum values for most of the parameters. This interaction enhanced dry weight per plant by 40.1%, P_N by 25.1% and leaf chlorophyll content by 28.8% at 75 DAS and seed yield per plant by 61.3%, oil yield per plant by 75.7% and fibre yield by 44.1% at harvest compared with Ca_0Mg_0 x Parvati which gave the lowest values. Moreover, $Ca_2Mg_{0.5}$ x Shubhra decreased lodging of plants by 35.9% at harvest compared with $Mg_{0.5}$ x Parvati (which was at par with Ca_0Mg_0 x Parvati) and gave the maximum value for lodging. It is noteworthy that the combined spray of Ca and Mg on Shubhra surpassed the effect of spray of Ca and Mg separately. Thus, $Ca_2Mg_{0.5}$ decreased lodging in Shubhra by 16.3% and 20.6% compared with Ca_2Mg_0 and $Ca_0Mg_{0.5}$ respectively.

In Chapter 5 (Discussion), the important results have been discussed in the light of the findings of earlier researchers particularly on linseed and other oilseeds in our laboratory and elsewhere.

The present chapter (Summary) is the resume of the thesis. It is followed by a bibliography of the references cited in the text. An appendix, containing the various formulations employed for chemical analyses, has been added at the end.

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Appendix

APPENDIX

GA_3 stock solution (10^{-2}M)

10^{-2}M stock solution of GA_3 was prepared by dissolving 0.346 g GA_3 in 10 ml ethyl alcohol, the final volume was made 100 ml using DDW.

Reagents for determination of carbonic anhydrase activity

1. Bromothymol blue indicator in ethanol (0.002%)

0.002 g bromothymol blue was dissolved in 10 ml ethyl alcohol, the final volume was made 100 ml using DDW.

2. Cystein hydrochloride solution (0.2 M)

48 g cystein hydrochloride was dissolved in sufficient volume of DDW and the final volume was made up to 1000 ml with DDW.

3. Hydrochloric acid (0.05 N)

4.3 ml pure hydrochloric acid was mixed with 95.7 ml DDW.

4. Phosphate buffer (0.2 M) for pH 6.8

This was prepared by dissolving 27.80 g sodium dihydrogen orthophosphate and 53.65 g di-sodium hydrogen orthophosphate in sufficient DDW separately and final volume of each was maintained up to 1000 ml with DDW. To get pH 6.8, 51 ml of monobasic sodium phosphate solution was mixed with 49 ml of dibasic sodium phosphate solution and diluted to 200 ml with DDW.

5. Sodium bicarbonate solution (0.2 M) in 0.02 M sodium hydroxide solution

16.8 g sodium bicarbonate was dissolved in 0.02 M sodium hydroxide solution (0.8 g NaOH/l) and final volume was maintained up to 1000 ml with the sodium hydroxide solution.

80% acetone

80 ml acetone was mixed with 20 ml DDW.

Reagents for the estimation of N, P, K, Ca and Mg

1. Aminonaphthol sulphonic acid

500 mg l-amino-2-naphthol-4-sulphonic acid was dissolved in 195 ml 15% sodium bisulphite to which 5 ml 20% sodium sulphite solution was added. The solution was kept in an amber coloured bottle.

2. Molybdic acid reagent

6.25 g ammonium molybdate was dissolved in 175 ml 10 N H_2SO_4.

3. Nessler's reagent

3.5 g potassium iodide was dissolved in 100 ml DDW in which 4% mercuric chloride was added with stirring until a slide red precipitate remains, then 120 g NaOH was mixed with 250 ml DDW. The mixture was kept in an amber coloured bottle.

4. Sodium hydroxide solution (2.5 N)

100 g sodium hydroxide was dissolved in sufficient volume of DDW and the final volume was maintained up to 1000 ml with DDW.

5. Sodium silicate solution (10%)

10 g sodium silicate was dissolved in sufficient volume of DDW and the final volume was made up to 100 ml with DDW.

6. Sulphuric acid (10 N)

27.2 ml sulphuric acid was mixed with 72.8 ml DDW.

7. Eriochrome black T indicator

0.5 g eriochrome black T and 4.5 g hydroxylamine hydrochloride were dissolved in approximately 100 ml of 95% ethyl alcohol.

8. Ammonium chloride-ammonium hydroxide buffer (pH 10)

67.5 g pure ammonium chloride was dissolved in 570 ml concentrated ammonium hydroxide solution and the final volume was made up to1000 ml with DDW, with pH adjusting to pH 10.

9. Ethylene diamine tetraacetic acid (EDTA) solution (0.01 N)

2.0 g disodium dihydrogen ethylene diamine tetra acetate and 0.05 g magnesium chloride hexahydrate were dissolved in sufficient volume of DDW and the final volume was made up to 1000 ml with DDW.

10. Potassium cyanide solution (1%)

1 g potassium cyanide was dissolved in sufficient volume of DDW and the final volume was made up to 100 ml with DDW.

11. Hydroxylamine-hydrochloride solution (5%)

5 g hydroxylamine-hydrochloride was dissolved in sufficient volume of DDW and the final volume was made up to 100 ml with DDW.

12. Potassium hexacyanoferrate (II) solution (4%)

4 g potassium hexacyanoferrate (II) was dissolved in sufficient volume of DDW and the final volume was made up to 100 ml with DDW.

Reagents for oil analysis

1. Iodine monochloride solution

13 g iodine was dissolved in a mixture of 300 ml carbon tetrachloride and 700 ml glacial acetic acid and the resulting solution was divided into solution A and B. To 20 ml of solution A, 15 ml potassium iodide solution and 100 ml DDW were added and titrated against 0.1 N sodium thiosulphate solution, using starch solution as an indicator.

2. Potassium iodide solution

150 g potassium iodide was dissolved in sufficient volume of DDW and the final volume was made up to 1000 ml with DDW.

3. Sodium thiosulphate solution

24.8 g sodium thiosulphate was dissolved in sufficient volume of DDW and the final volume was made up to 1000 ml.

4. Starch solution (1%)

1 g soluble starch was dissolved in sufficient volume of boiling DDW and the final volume was made up to 100 ml of boiling DDW.